CHAPTER 7. LIFE-CYCLE COSTS AND PAYBACK PERIOD

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 7. LIFE-CYCLE COSTS AND PAYBACK PERIOD

7.1 INTRODUCTION

This chapter describes the method for analyzing the economic impacts of possible standards on individual consumers. The effect of standards on individual consumers includes a change in operating expense (usually decreased) and a change in purchase price (usually increased). This chapter describes three metrics used in the consumer analysis, to determine the effect of standards on individual consumers:

- Life-cycle cost (LCC) captures the tradeoff between purchase price and operating expenses for appliances.
- Payback period (PBP) measures the amount of time it takes consumers to recover the assumed higher purchase expense of more energy-efficient equipment through lower operating costs.
- Rebuttable Payback Period (RPP) is a special case of PBP. Where LCC and PBP are estimated over a range of inputs reflecting actual conditions, Rebuttable Payback Period is based on laboratory conditions, specifically, DOE test procedure inputs.

These are discussed in sections 7.2, 7.3 and 7.4 of this chapter, respectively. Inputs and results are presented for each metric. Key quantities, current assumptions and calculations are detailed for each metric. The calculations discussed here are performed on a series of Microsoft Excel™ spreadsheets which are accessible over the Internet.

7.1.1 General Approach for LCC and Distribution PBP

In recognition that each household is unique, variability is analyzed in order to account for many of the differences among them by performing the calculations detailed here for a large sample of individual households. The results are expressed as the number of households having impacts of particular magnitudes. The LCC and PBP model was developed using Microsoft Excel™ in Windows 95™, combined with Crystal Ball™ (a commercially available add-in, available at http://www.decisioneering.com).

The analysis explicitly specifies both the uncertainty and variability in the model's inputs using probability distributions. A Monte Carlo simulation then takes thousands of random samples from each probability distribution within the model to calculate the outputs. Each input probability distribution is sampled in a way that reproduces the distributions' shape. The distribution of the results therefore reflects the probability of the values that could occur given the range of input values. This technique helps provide an insight into the likelihood of various possible results.

The results are typically displayed as distributions of the impact examined as compared to the baseline. The following charts were created: i) a cumulative probability distribution showing the percentage of American households which would have a net saving by owning a more energy efficient appliance or ii) a frequency chart that depicts variation of the difference in life-cycle cost for each efficiency level considered.

7.2 LIFE-CYCLE COST (LCC)

7.2.1 Definition

Life-cycle cost is the total consumer expense over the life of an appliance, including purchase expense and operating expenses (including energy expenditures). Future operating expenses are discounted to the time of purchase, and summed over the lifetime of the appliance. Life-cycle cost is defined by the following equation:

$$LCC = P + \sum \frac{O_t}{(1+r)^t} \qquad \textbf{(1)}$$

where:

P	=	Purchase expense ($)
∑	=	Sum over the lifetime, from year 1 to year N, where N = lifetime of appliance (years)
O	=	Annual operating expense ($) [*Note:* for clothes washers O = (cycles per year) * {(energy per cycle) * (energy rate) + (water per cycle) * (water rate)}]
r	=	Discount rate (real)
t	=	Years after purchase of appliance

7.2.2 LCC Inputs

This section provides information about the quantities and assumptions used to calculate life-cycle cost for clothes washers. For each quantity, the discussion includes:

- definition
- approach
- current assumption

Inputs for the LCC analysis are shown in Table 7.1 below.

Table 7.1 Quantities in LCC Spreadsheet

Purchase expense ($)
Lifetime (years)
Cycles per year
Energy per cycle (kWh/cycle)
Electricity rate (cents/kWh)
Gas rate ($/MMBtu)
Oil price ($/MMBtu)
LPG price ($/MMBtu)
Water per cycle (gallons)
Water rate ($/thousand gallons)
Discount rate
Water Heater/ Dryer Share
Year to Start Date
Base Case Design
Standard Case Design

7.2.2.1 Purchase Expense

Definition. Consumer expense for purchasing an appliance.

Approach. Consumer purchase expense includes the retail price of the appliance plus sales tax. The baseline purchase expense is the retail price plus sales tax for a clothes washer at the baseline efficiency level. The baseline price is a shipment weighted average (SWA) price of washers currently being sold. Efficiency and price are not necessarily related for clothes washers; price is more a function of features and brand name.

Example of Baseline Purchase Expense (all values in this description are rounded to the nearest dollar):

Baseline retail price = $400
Sales tax (U.S. average) = 5.2%
Therefore, baseline purchase expense = $421

The purchase expense for each efficiency level is calculated as the sum of baseline purchase expense plus the incremental purchase expense for the efficiency level. The incremental purchase expense is the product of incremental manufacturing cost, manufacturer variable markup, and retail variable markup, plus the sales tax. The Association of Home Appliance Manufacturers (AHAM) provided incremental manufacturing costs for 9 efficiency levels.

For example, the incremental manufacturing cost (shipment-weighted average) for a 35% energy reduction from baseline is $128, with a customized distribution provided by AHAM. The mean manufacturer variable markup is 1.27 (range of 1.26 to 1.28, uniform distribution), retail variable markup is 1.40, and sales tax adds 5.2% to the retail price. The incremental purchase expense is: $128 x 1.27 x 1.40 x 1.052 = $239. The purchase expense for the unit having a 35% energy reduction is the baseline purchase expense plus the incremental purchase expense = $421 + 239 = $660. A distribution of prices is used for the LCC analysis based on a distribution of incremental manufacturing costs and a distribution of markups. Single values are shown in this discussion for illustration purposes only.

Note that some of the incremental costs and markups are treated as distributions while others are treated as fixed numbers that represent the averages. The incremental manufacturing cost is treated as a distribution that is weighted according to the current manufacturer market shares. The manufacturer markup on incremental cost increases is also a distribution that ranges between a minimum and maximum markup and has constant probability in this range. The range of manufacturer markups is determined from the manufacturer impact analysis. In contrast to the manufacturer markups, the retail and tax markups are fixed at their average values.

Assumptions. AHAM data is used for manufacturing costs. Data compiled by Arthur D. Little (ADL) is used for markups and sales tax. In addition, we assume in the current calculations that there is no price-based shift in consumer equipment choices.

7.2.2.2 Lifetime

Definition. The period of time the clothes washer will provide service.

Approach. The lifetime is estimated by comparing historical shipments to percent of households owning the appliance.[1]

Assumption. For clothes washers, lifetimes range from 12 to 16 years, with an average of 14.1 years. Figure 7.1 shows the percent of washers surviving since year of original purchase.

Figure 7.1 Percent of Clothes Washers Surviving since Year of Original Purchase

7.2.2.3 Cycles Per Year

Definition. Loads of laundry washed per household per year.

Approach. The DOE test procedure assumes 392 cycles per year. In actuality, the number of loads of laundry washed per household per year depends upon the number of persons in the household and on other factors. A survey of U.S. households indicates a relationship between family size and cycles per year.[2] Using the sample of households having both a clothes washer and a clothes dryer from the Energy Information Administration's 1993 Residential Energy Consumption Survey (RECS),[3] we assigned a cycles per year value to each household according to the persons per household. The weighted average result is 379 cycles per year for the U.S. mix of households. This value agrees closely with (is 4% lower than) the DOE test procedure. To the extent that households use different fuels for water heaters and clothes dryers, the cycles per year also differ among those households.

Assumption. To simulate a sample of households, each household is assigned a given number of cycles per year based upon Table 7.2 (the values are then scaled so the average agrees with the test procedure assumption). Figure 7.2 shows the percent of households (i.e., the weighting of households) for a given number of washer cycles per year.

Table 7.2 Cycles per Year for Persons per Household

Persons per household	Cycles per year	Cycles per year (scaled)
1	200	207
2	310	321
3-4	454	469
5+	624	645

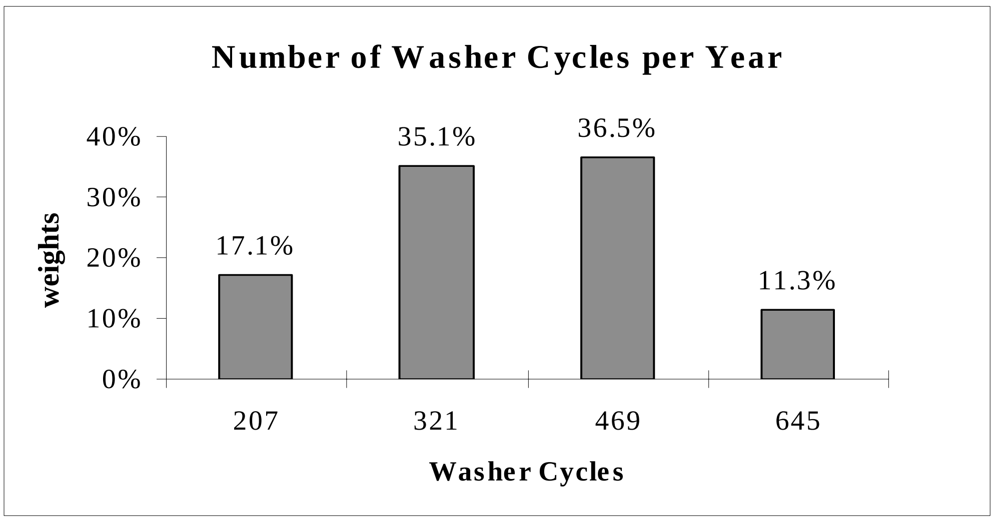

Figure 7.2 Weighting of the Number of Washer Cycles per Year

7.2.2.4 Energy Per Cycle

Definition. Energy consumed per cycle. One cycle corresponds to one load of laundry.

Approach. In accordance with the DOE test procedure (for modified energy factor, MEF), energy consumption per cycle includes electricity used by the clothes washer, and energy used by the water heater to provide hot water, and energy used by the clothes dryer to dry the clothing.

Assumptions. Each of these components of energy consumption per cycle is obtained from data submitted by AHAM, for both the baseline and the various efficiency levels (see TSD Engineering Analysis). The following equations show the relationship between energy use per cycle and MEF.

$$\textit{Energy per cycle} = \textit{motor energy} + \textit{energy to heat water} + \textit{energy to dry clothes} \tag{2}$$

$$MEF = \frac{\textit{capacity (cu. ft.)}}{\textit{energy per cycle}} \tag{3}$$

7.2.2.5 Electricity Marginal Prices

Definition. The value to a residential customer of saving electricity, expressed as cents per kilowatt-hour.

Issues. All households with clothes washers use electricity for the washer, and some households use electricity for water heating and clothes drying as well. Showing the change the customer will see in his/her electricity bill due to increased energy efficiency is complex because: 1) electricity rate varies from house to house, depending upon the rate schedule charged by the utility and the consumption pattern of the particular customer; and 2) future rates cannot be known with certainty, especially since the market is currently restructuring and a growing number of consumers are able to choose among competing utilities.

Approach. The variations in electricity rate are handled by separating the problem into three parts: a) variability in energy rate among households; b) value of savings; and c) future trends. Each of these parts is discussed and current assumptions are described. A significant change from previous analyses is the use of marginal electric prices. Marginal prices refer to what the electric price is for the last incremental kWh used. This is further discussed in the sub-heading on the value of savings.

a) Variability. The Energy Information Administration's 1993 RECS gathered information on electricity bills which is used to represent the variability from house to house[3]. An advantage of using a survey containing information on specific households is the ability to directly capture correlations among quantities. Such correlations are important for electric and gas prices, for example, or among household characteristics (e.g., fuel of the water heater and clothes dryer, persons per household) that affect energy consumption. Figure 7.3 shows the distribution of marginal electricity prices.

Assumption regarding variability*:* All those households with complete information from RECS which have both a clothes washer and a clothes dryer are used. Energy prices are reported in the survey results for each household. These households are assigned weights to represent the U.S. Marginal residential electricity prices derived from RECS in Figure 7.3 were adjusted to 1997 prices in 1997 dollars by multiplying the marginal prices derived from RECS by the ratio of average national residential electricity price in 1997 and the average national residential electricity price in 1993[4] In other words, the conversion to change 1993 RECS household prices to 1997 prices is the ratio of 1997 national average residential prices by 1993 prices, with both prices in current years. This takes into account both inflation and the real change in prices.

b) Value of Savings.

The prices shown in Figure 7.3 are marginal prices empirically derived from RECS. The RECS data on residential energy use includes information on the monthly billing and energy use for the surveyed households. The electricity use from month-to-month has a natural variability that allows one to calculate the effective marginal price of electricity. We therefore calculated seasonal marginal electricity prices by measuring the slope of a linear least squares fit of the relationship between energy use and cost. The data was divided into a summer and non-summer season. Summer was defined in the analysis as June 1 to September 30, so if the midpoint of the billing period fell within that date range the bill was defined as a summer bill. As it turned out the summer/winter distinction is not important for clothes washers, since the average summer clothes washer use is equal to the average use for the rest of the year. For some surveyed households the billing data was not available, or the data was not of sufficient quality for the marginal energy rate analysis. Households for which marginal energy prices could not be calculated were eliminated, resulting in a reduction of approximately 10% of the households used from RECS. The households that were excluded from the marginal rate analysis tended to be those households where the utility bill was included in the rent. For details on the methods and results, see the full report on the marginal price research effort, Marginal Energy Prices Report, available on DOE's website.[5]

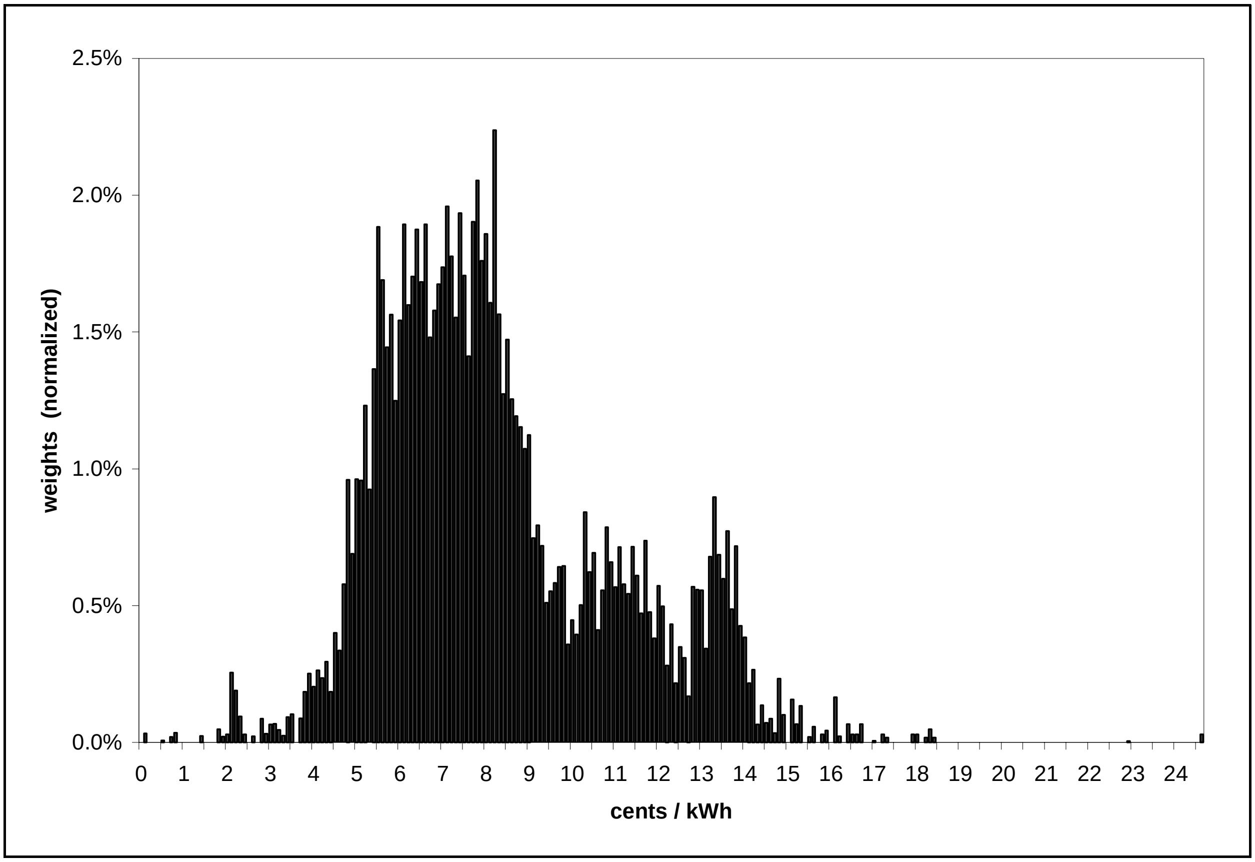

Figure 7.3 Distribution of 1997 Marginal Residential Electricity Prices (In 1997$)

c) Future Trend. Estimating future electricity rates is now more difficult than ever. In some states, the electricity supply industry is undergoing restructuring. Previously, each household was assigned to a particular utility company, and the rates offered by that utility obtained from surveys. In the future, with restructuring, households will be able to purchase electricity from a large set of suppliers.

A projected trend in national average prices is applied to each household's marginal energy prices. The price trend is applied by assuming that the household's energy prices vary in proportion to the projected national average energy price. In the spreadsheets, the user can select from the following scenarios:

1) Constant energy prices at 1997 values
2) Energy Information Administration Annual Energy Outlook 1999,(AEO99)[6] High Economic Growth
3) Energy Information Administration Annual Energy Outlook 1999, Reference Case
4) Energy Information Administration Annual Energy Outlook 1999, Low Economic Growth
5) Gas Research Institute 1998 Baseline Projection[7]

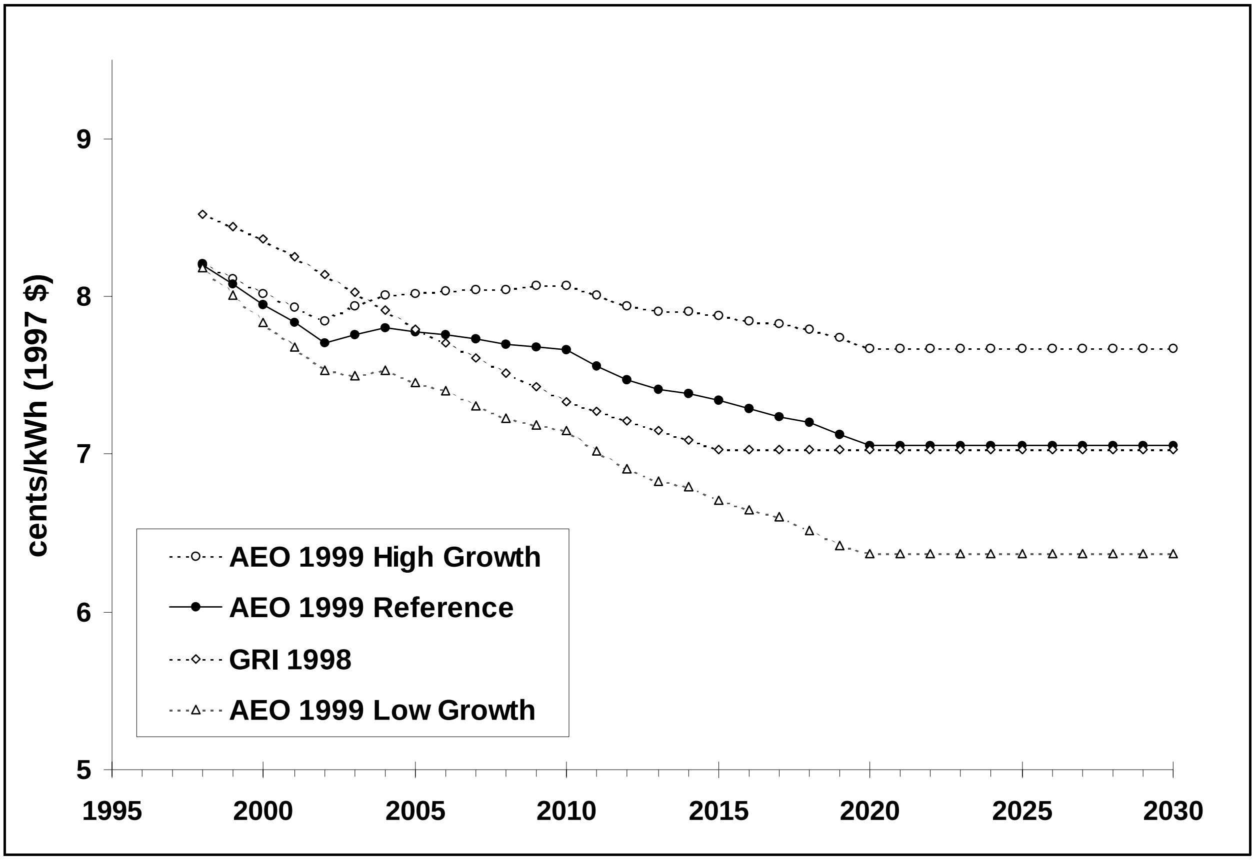

Figure 7.4 Alternative Electricity Price Trends

Figure 7.4 shows the trends for the last four of those projections.[a] The values in later years (i.e. after 2015 for GRI and after 2020 for all others) are extrapolated from their earlier years. Extrapolation is needed because the sources used do not forecast beyond 2020 (or 2015 in the case of the GRI forecast). With the GRI forecast, prices are simply left constant at 2015 levels. For the AEO99 projections, electricity prices are kept constant at 2020 levels because it is assumed that the transition to a restructured utility industry will be completed.

Assumption regarding future trend: This analysis assumes the trend from AEO99 Reference Case. In addition, a sensitivity analysis was performed at AEO high and low economic growth assumptions..

[a]Although for purposes of the LCC analysis, fuel price data is not needed beyond 2020, additional data is presented here up to the year 2030. National impacts discussed elsewhere are determined to the year 2030.

7.2.2.6 Gas Marginal Prices

Definition. The value to a residential customer of saving gas, expressed as dollars per million Btu.

Issues. Some households use gas for their water heater or clothes dryer. Showing the change the customer will see in his/her gas bill due to increased energy efficiency is complex because: 1) gas rate varies from house to house, depending upon the rate schedule charged by the utility and the consumption pattern of the particular customer; and 2) future rates cannot be known with certainty.

Approach. The variations in gas rate are handled by separating the problem into three parts: a) variability in energy price among households; b) value of savings; and c) future trends. Each of these parts is discussed and current assumptions described.

a) Variability. The RECS survey gathered information on gas bills which is used to represent the variability from house to house. An advantage of using a survey containing information on specific households is the ability to directly capture correlations among quantities. Such correlations are important for electric and gas rates, for example, or among household characteristics (e.g., fuel of the water heater and clothes dryer, persons per household) that affect energy consumption.

***Assumption regarding variability**:* All those households from the RECS survey which have both a clothes washer and a clothes dryer are used. For each household, relevant energy prices are reported. These households are assigned weights to represent the U.S. Figure 7.5 shows residential marginal gas prices ranging from approximately 2 to 17 \$/million Btu (MMBtu).

b) Value of Savings. The prices shown in Figure 7.5 are marginal prices empirically derived from RECS. The RECS data on residential energy use includes information on the monthly billing and energy use for the surveyed households. We used an empirical approach to calculate marginal energy rates. The RECS data on residential energy use includes information on the monthly billing and energy use for the surveyed households. The energy use from month-to-month has a natural variability that allows one to calculate the effective marginal price of energy. We therefore calculated marginal energy prices by measuring the slope of a linear least squares fit of the relationship between energy use and cost. Unlike for the electricity marginal price determination, gas marginal prices were not separated into summer and non-summer divisions.

For some surveyed households the billing data was not available, or the data was not of sufficient quality for the marginal energy rate analysis. Households for which marginal energy prices could not be calculated were eliminated, resulting in a reduction of approximately 10% of the households used from RECS. The households that were excluded from the marginal rate analysis tended to be those households where the utility bill was included in the rent.

For details on the methods and results of the marginal energy price calculations, see the full report on marginal prices.[5]

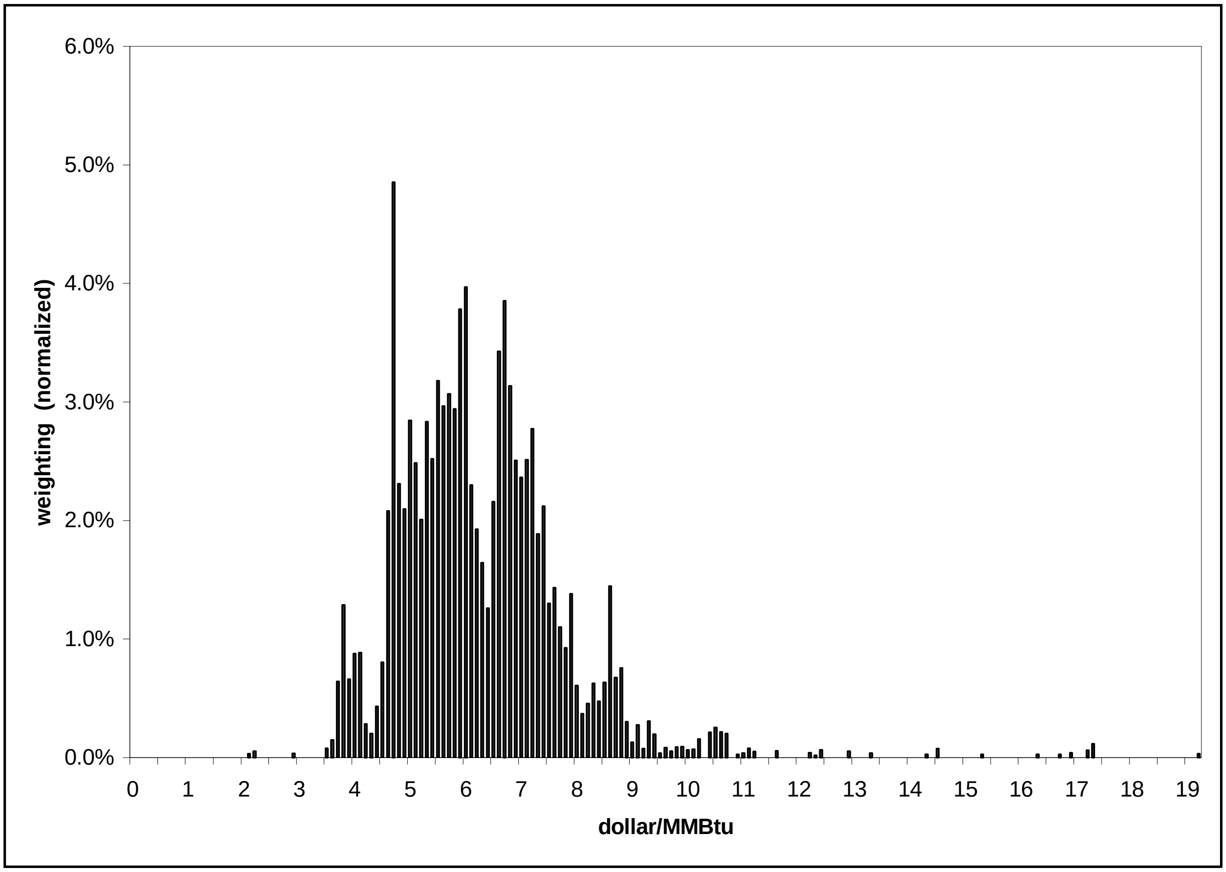

Figure 7.5 Distribution of 1997 Marginal Residential Gas Prices (In 1997$)

c) Future Trend. A projected trend in national average prices is applied to each household's energy prices, after accounting for "value of savings" (described above). In the spreadsheets, the user can select from the following scenarios:

1) Constant energy prices at 1997 values
2) Energy Information Administration Annual Energy Outlook 1999, High Economic Growth
3) Energy Information Administration Annual Energy Outlook 1999, Reference Case
4) Energy Information Administration Annual Energy Outlook 1999, Low Economic Growth
5) Gas Research Institute 1998 Baseline Projection.

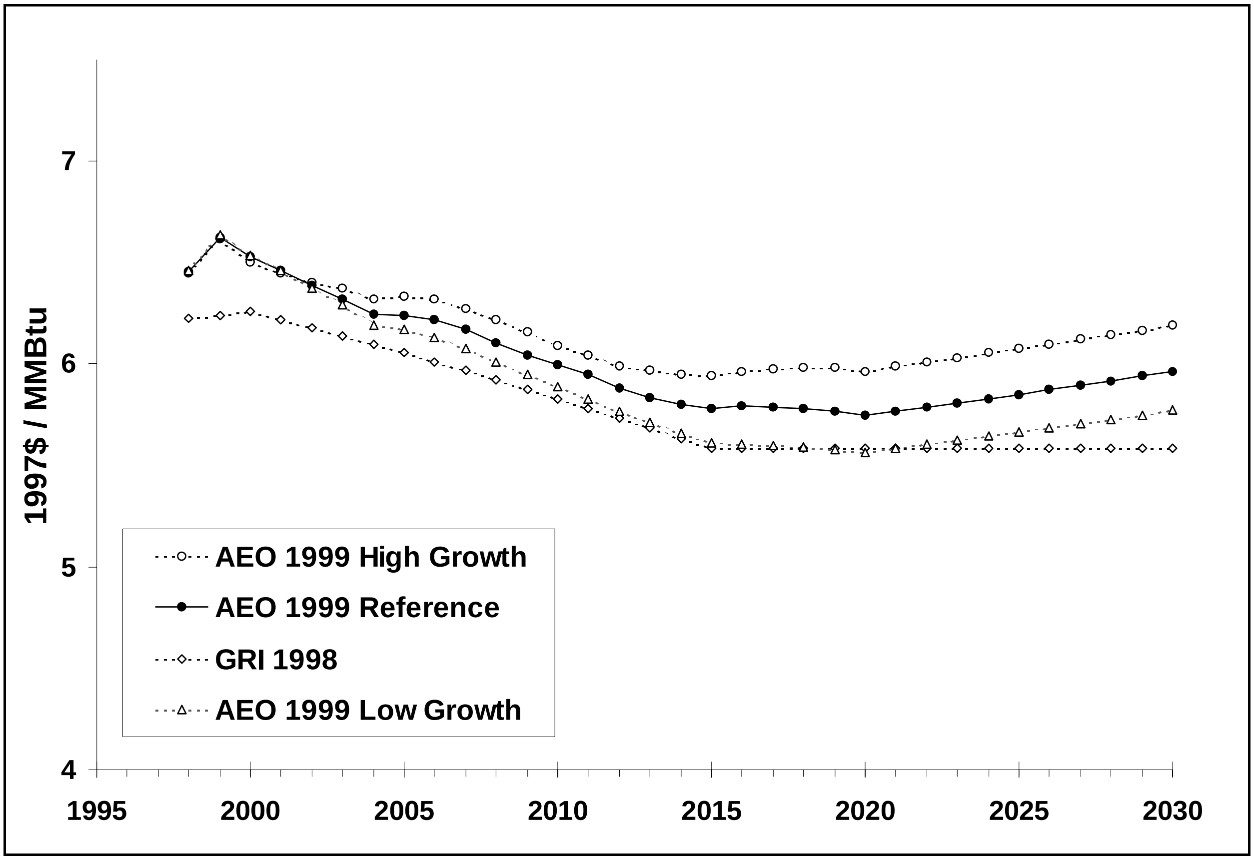

Figure 7.6 Alternative Natural Gas Price Trends

Figure 7.6 shows the projections. The values in later years (i.e. after 2015 for GRI and after 2020 for all others) are extrapolated from their relative sources Extrapolation is necessary because the sources used do not forecast beyond 2020 (or 2015 in the case of the GRI forecast). To arrive at values for these later years forecast prices are simply left constant 2015 levels for GRI. For AEO99 projections, extrapolated values are the same as used by the Federal Energy Management Program (FEMP).[8] Wellhead natural gas prices after 2020 were extrapolated to 2030 using the average annual growth rate from 1997 to 2020. The regional, end-use margins (end-use minus wellhead prices) in 2020 were added to the wellhead natural gas price from 2021 to 2030 to arrive at regional, end-use prices.

Assumption regarding future trend. This analysis assumes the trend from the AEO99 Reference Case. In addition, sensitivities analysis is performed at AEO high and low growth projections.

7.2.2.7 Oil Prices

Definition. Residential price of distillate.

Approach.
a) Variability and value of Savings. Variability in prices is taken from the RECS sample and adjusted to 1997 prices. No attempt is made to define a consumer marginal energy rate.

b) Future Trend. Figure 7.7 shows the oil price time trend. The values in later years (i.e. after 2015 for GRI and after 2020 for all others) are extrapolated from their relative sources. Extrapolation is necessary because the sources used do not forecast beyond 2020 (or 2015 in the case of the GRI forecast). For GRI projections beyond 2015 values are simply left constant at 2015 prices.

Since the AEO99 version of NEMS forecasts only to the year 2020, we had to use a method for extrapolating price data to 2030. The method that we adopted uses the EIA approach to forecast fuel prices for FEMP.

Assumptions. Variability in price from 1993 RECS sample of households owning washers and dryers. The future trend is taken from the AEO 1999 Reference Case.

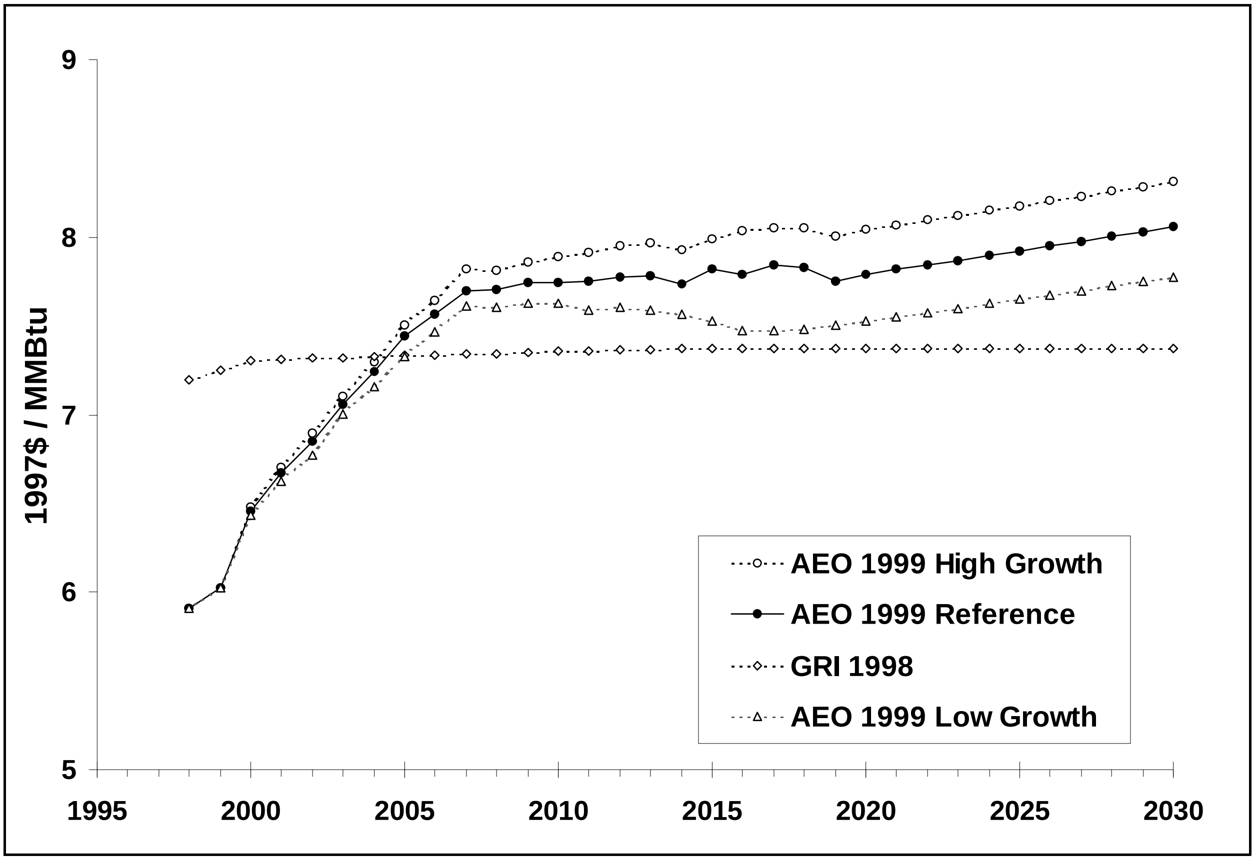

Figure 7.7 Alternative Oil Price Trends

7.2.2.8 LPG (propane) Prices

Definition. Residential price of LPG.

Approach.
a) Variability and Value of Savings. Variability in prices is taken from the RECS sample and adjusted to 1997 prices. No attempt is made to define a consumer marginal energy rate.

b) Future Trend. Figure 7.8 shows the LPG price tiime trend. LPG prices beyond 2020 are the same as those forecasted by EIA to forecast fuel prices for FEMP. GRI projections for LPG were not available so the prices for the AEO99 Reference Case were used with the exception of keeping the price constant after 2015 to be consistent with the way GRI projections were dealt with for other fuels.

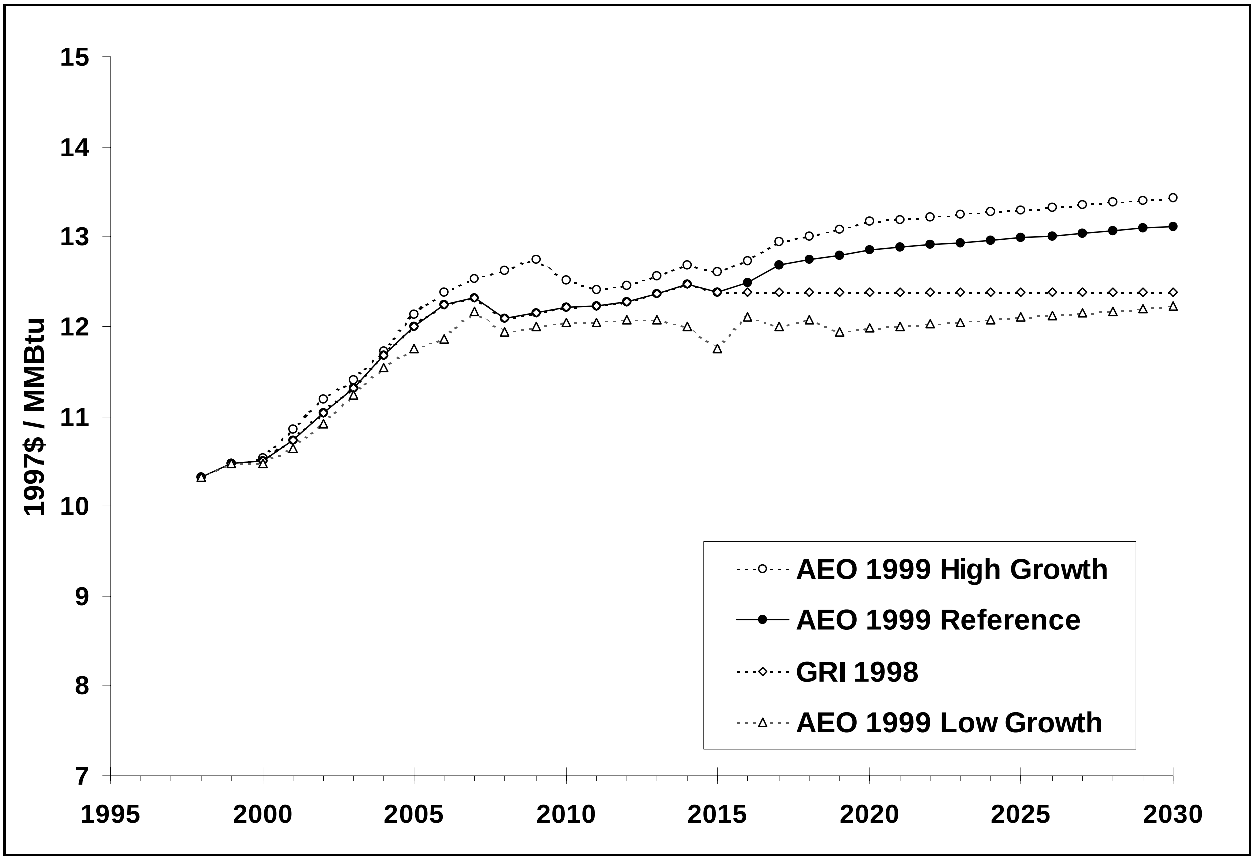

Figure 7.8 Alternative LPG Price Trends

7.2.2.9 Water per Cycle

Definition. Water consumed by clothes washer in one cycle.

Approach. Data as submitted by AHAM. [9]

Current Assumption. Use numerical values for baseline and each efficiency level, as provided by AHAM. Figure 7.9 shows the water use per cycle vs. modified energy factor (MEF).[a]

[a] Data for the figure were provided by clothes washer manufacturers and then aggregated for this analysis; see TSD Engineering Analysis for further details.

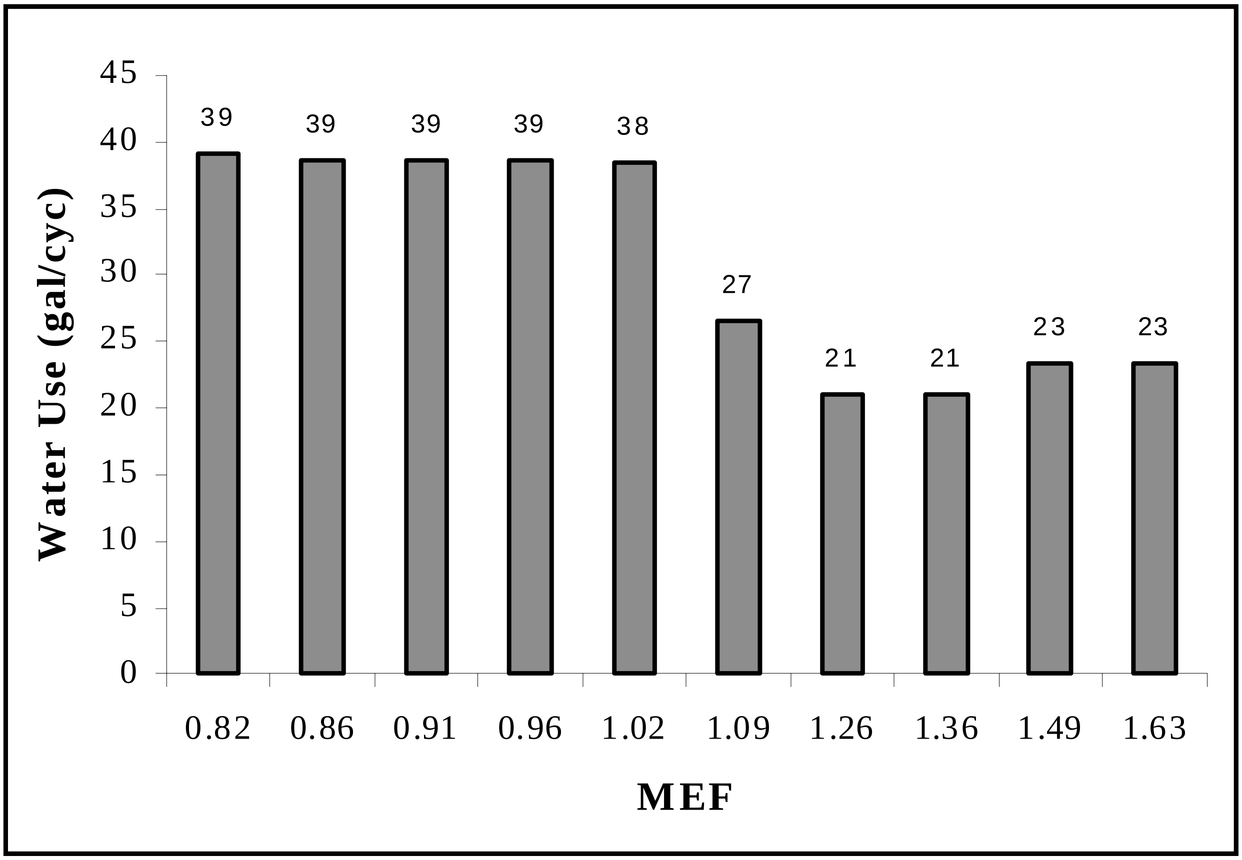

Figure 7.9 Water use Per Cycle vs. MEF

7.2.2.10 Water and Wastewater Removal Prices

Definition. Residential customer price for water and wastewater (sewer) (expressed in $/ thousand gallons), excluding fixed charges.

Issues. The typical single family home uses 22.7% of its water on clothes washers.[10] Price and price escalation rates for water and wastewater need to be determined; unlike fuel prices, RECS does not provide information on water prices. The price relevant to the LCC is the marginal price, the incremental cost of water for each gallon saved.

Background & Overview. In the preliminary TSD analysis, we based water and wastewater prices on urban data only. Stakeholder comments at the November 1998 DOE clothes washer workshop suggested that rural water and rural sewage rates should also be considered in the analysis. A water utility consultant, Raftelis Environmental Consulting Group, disaggregated water & wastewater utilities into three utility size categories and reported that the largest utilities as a group had lower water and wastewater charges than the smallest utilities.[11] Assuming that, on average, rural households are served by smaller utilities, we used urban water and/or sewer rates as an approximation of connected water and sewer rates in rural areas; i.e., we assumed rural water and wastewater removal prices to be at least as high as those charged by urban utilities. For households not having a wastewater utility, only the urban water price was used. For households having individual wells and septic systems, only the cost to pump water was used.

Approach. There are two objectives of the water and wastewater price study:

- distribution of current prices consumers pay to purchase water and dispose of wastewater, and
- projection of water and wastewater prices into the future.

Current Price Distribution Data. The most extensive current data containing both water and wastewater pricing was compiled by Raftelis.[12] The 1998 Raftelis survey data was used for the distribution of water and wastewater prices. A water usage of 10 ccf [a] per month was assumed for the analysis. To be consistent with other data in the LCC and NES spreadsheets, prices were converted to 1997 dollars. The database included 115 service areas (cities) representing a population of approximately 56 million. Because water prices can vary widely even within a small geographic area, average national values were used rather than separating values by region.

Marginal price. The marginal price was estimated by subtracting the fixed prices or minimum charges from the monthly wastewater charge and from the total charges for a water usage of 10 ccf per month. The marginal prices for water and wastewater were added together and the units were converted to dollars per 1000 gallons. A weighted marginal price was ascertained from the product of the marginal price and the population weighting for each utility. For households not having a utility wastewater removal service, only the water price was used. In addition, water cost was estimated for households having individual well pumps and a septic tank. See Appendix F for additional detail. The distribution of marginal water and wastewater prices and water-only prices are shown in Figures 7.10 and 7.11, respectively.

[a] ccf = hundreds of cubic feet (cu. ft. x 7.48 = U.S. gallons)

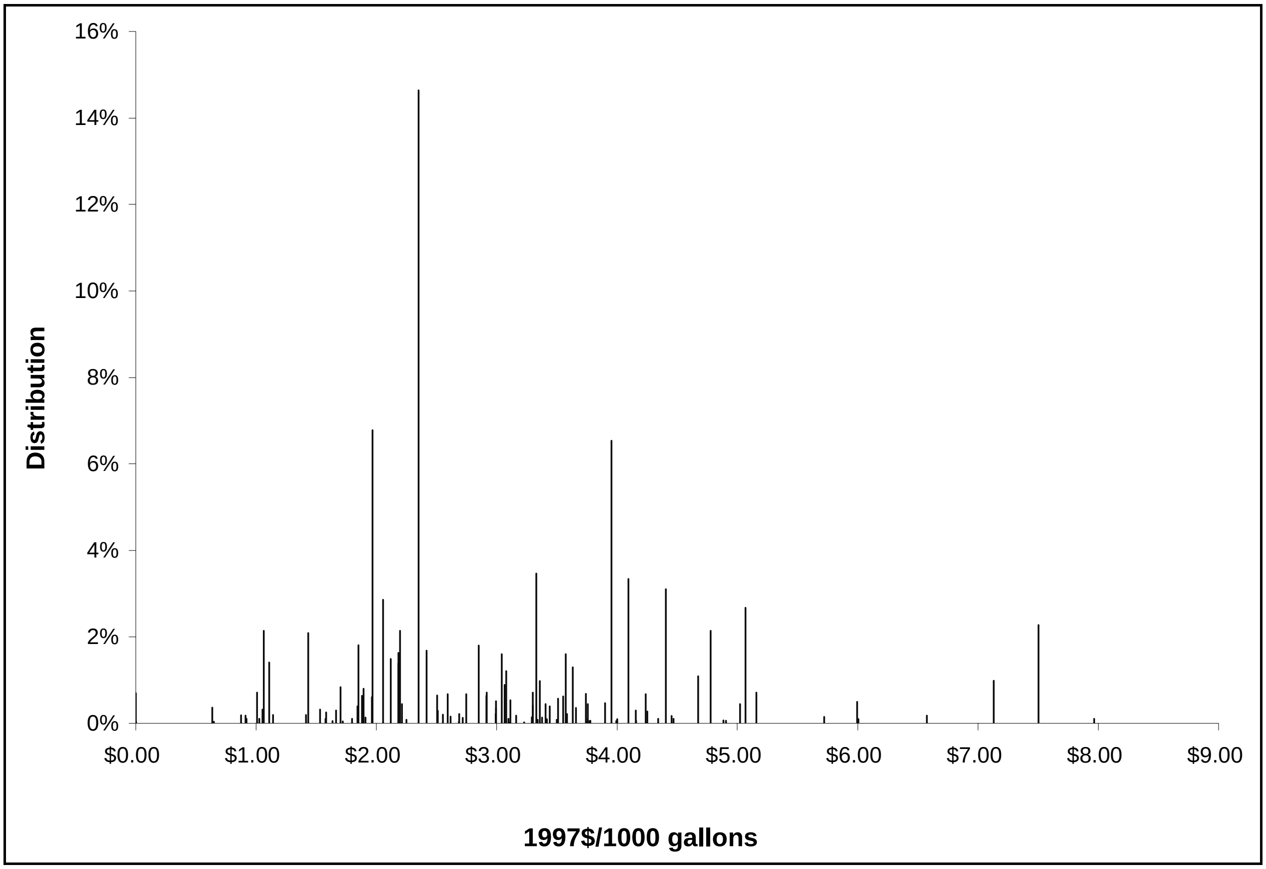

Figure 7.10 1998 Urban Water & Wastewater Price Distribution, in 1997 Dollars

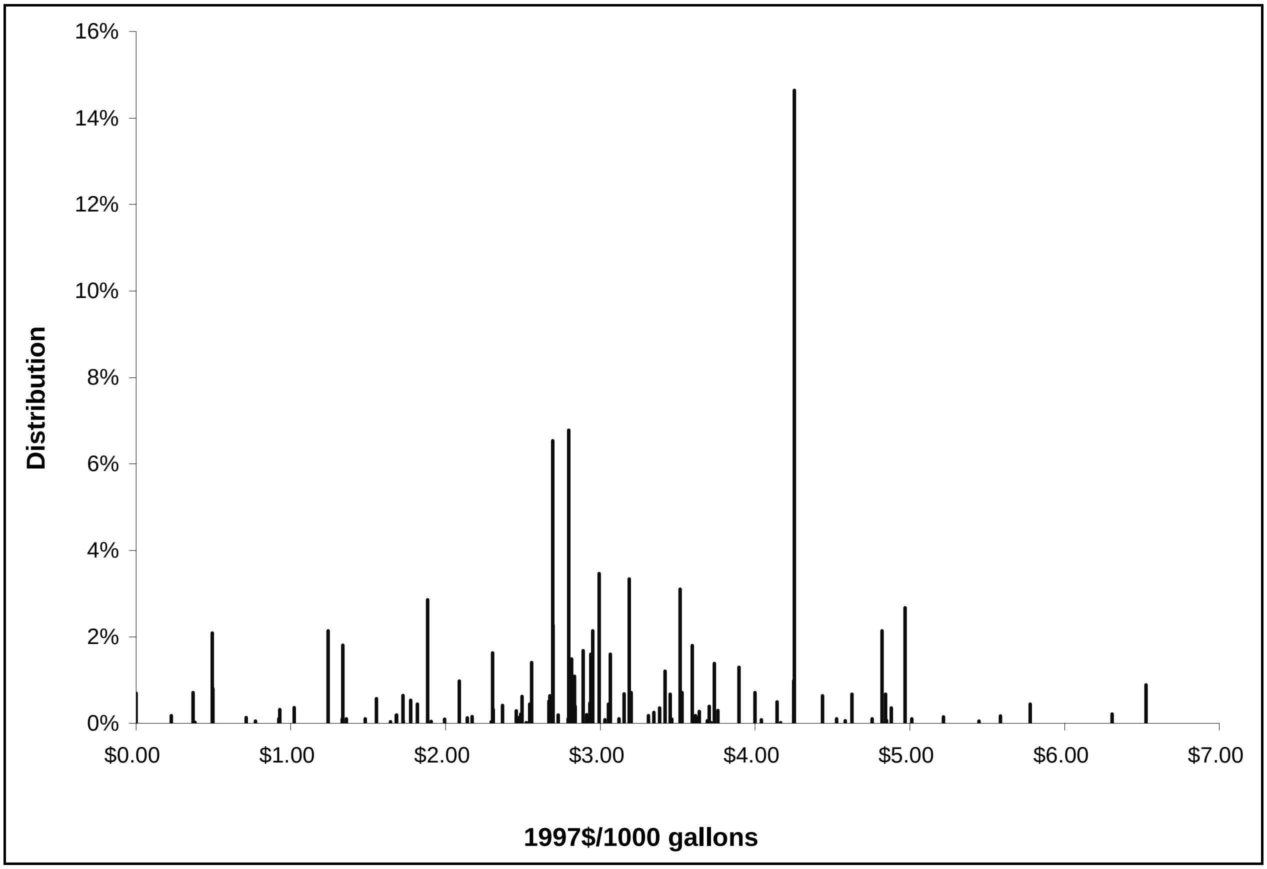

Figure 7.11 1998 Urban Water Price Distribution, in 1997 Dollars

Price Escalation Data. The escalation of water and wastewater disposal costs, i.e., the rate at which water and wastewater prices are changing, was determined through an examination of trends in historical prices. Future trends for average, high, and low prices were estimated. Figure 7.12 summarizes these trends. See Appendix F for a detailed discussion of the development of these price data and their use in the LCC spreadsheet.

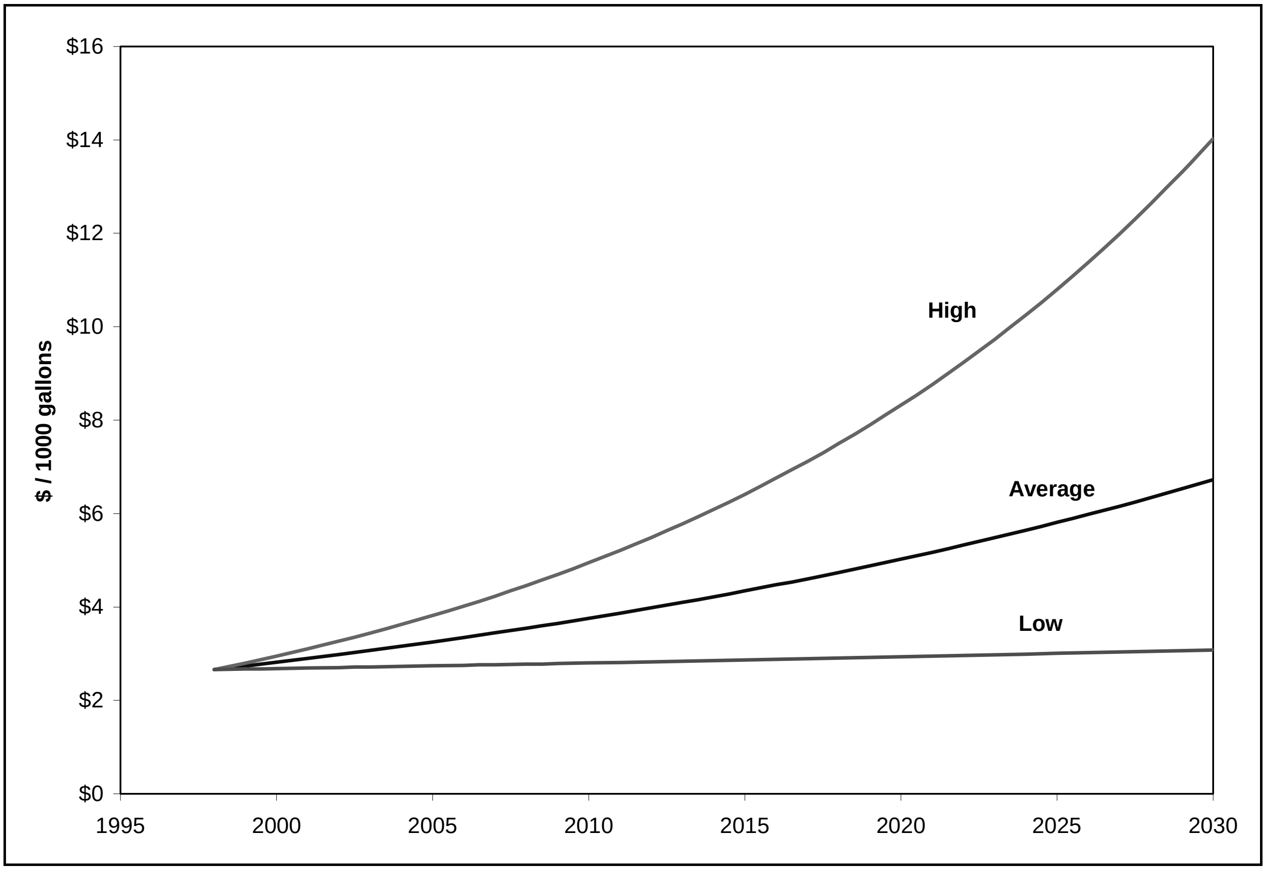

Figure 7.12 Water and Wastewater Price Trends

7.2.2.11 Discount Rate

Definition. The rate at which future expenditures are discounted to establish their present value.

Approach. A distribution of discount rates was derived to represent the variability in financing methods consumers use in purchasing appliances. The resulting distribution of discount rates is used to calculate a distribution of life-cycle costs for clothes washers. Table 7.3 summarizes the interest rate assumptions discussed below.

Table 7.3 Summary of Nominal Interest Rates

Financing	Percent of Clothes Washer	Range of Real Interest Rates		
		Minimum	Maximum	Mean
New home (after	20%	1.60%	3.76%	2.68%
Cash	32%	0.00%	3.00%	1.50%
Credit Card	28%	6.00%	15.00%	10.5%
Retailer Loan	20%	6.00%	15.00%	10.50%

Consumer Purchase and Financing Methods. Consumers purchase appliances in new homes and as retail purchases. The retail purchases are paid by cash, credit cards, or retailer loans. A stakeholder comment indicated that for white goods about 40% of retail purchases are paid in cash, 35% use credit cards, and 25% use retailer loans [13]. The same comment indicates 25% of appliance purchases are for new homes. (For clothes washers, DOE estimates that purchases for new homes are now about 20%.) The method of purchase used by consumers is assumed to be indicative of the source of the funds and the type of financing used by these consumers.

Interest Rates. DOE estimated a range of interest rates that may reasonably be expected to apply in the future to different types of consumer savings or financing. These are estimates, based upon historical data and judgment about how the future may differ from the historical period.

For new housing, DOE estimated nominal mortgage rates (5-8%), derived the after-tax rate assuming a tax of 28%, then subtracted the inflation rate (assume 2%). The result is a range of real mortgage rates of 1.60-3.76%. (Example: 5% * (100%-28%) - 2% = 1.6%)

For cash, the minimum rate is 0%. This rate applies to purchasers making cash purchases without withdrawing from savings accounts. The maximum is taken to be the opportunity cost represented by the interest that could have been earned in a savings account. The historical nominal maximum savings rate ranged from 4.5-5.5% from 1970 to 1986 (real rates of -8.27 to +3.58%). A real rate of 3% as indicative of the maximum.

The interest rates for retailer loans and credit cards are assumed to have the same range. The minimum credit card rate is taken as 6% real. Introductory rates on some credit cards today are 5.9% nominal, but after the introductory period (often 6 months), the rate becomes much higher. Maximum rates are over 20% nominal. On the other hand, most retail purchasers will not make payments for a clothes washer over the entire lifetime (12-16 years) of the appliance. If the purchase is paid for initially by a credit card, but the consumer pays off the balance in less than the life of the washer, then the effective interest rate is lower than the nominal credit card rate. The current assumption is a range of 6-15% real.

Assumption. The real interest rate associated with financing an appliance purchase or with the savings from which the necessary funds were drawn are good indicators of the additional costs incurred by consumers who pay a higher first cost, but enjoy future savings. For this reason, it is assumed that these rates are appropriate discount rates for use in this analysis. Table 7.4 summarizes the ranges of discount rates used in the LCC distribution analysis, derived from the analysis of financing methods described above. Figure 7.13 shows the distribution of real discount rates, ranging from 0 to 15%, with a mean of 6%. The weights noted on the y-axis indicate percent of purchases.

Table 7.4 uses the data in Table 7.3 and accounts for overlap between the new home and cash interest rates.

Table 7.4 Distribution of Discount Rates

Minimum Value	Maximum Value	Probability
0.00%	1.60%	17%
1.60%	3.00%	28%
3.00%	3.76%	7%
3.76%	6.00%	0%
6.00%	15.00%	48%

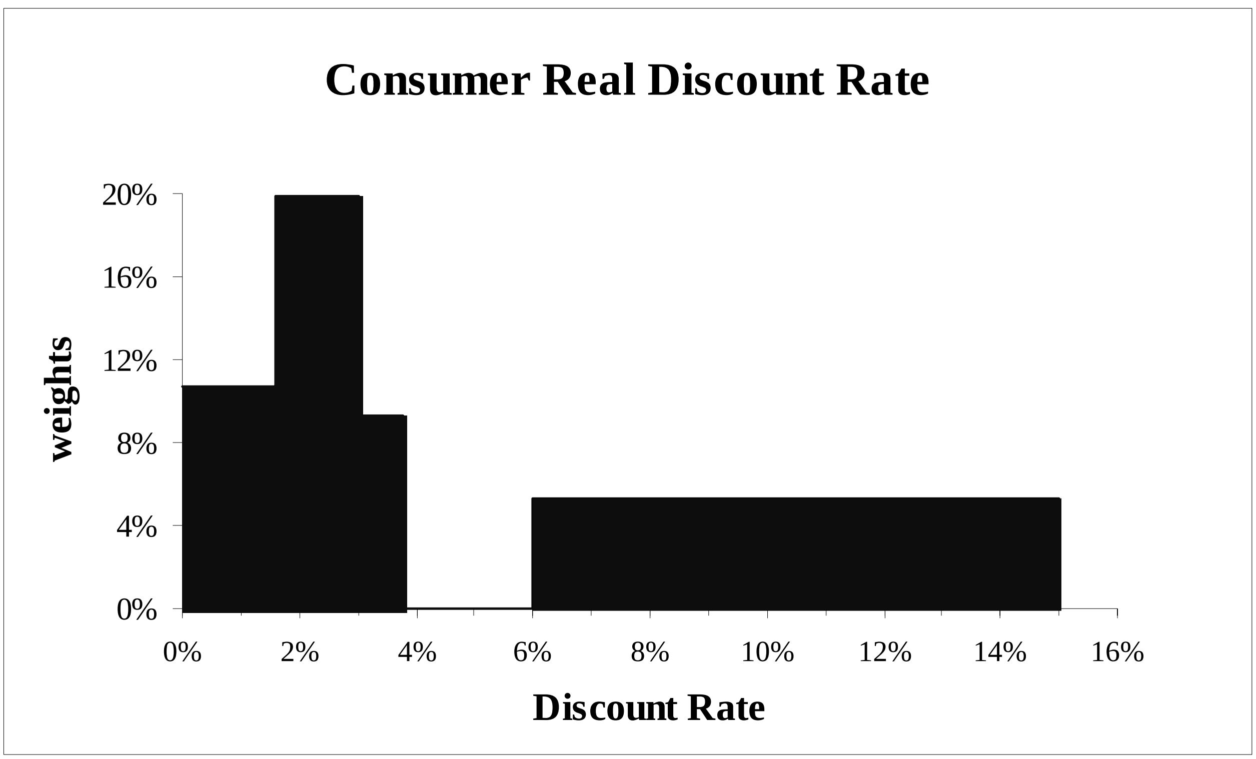

Figure 7.13 Distribution of Consumer Discount Rates

DOE recognizes that other factors might be considered in the estimation of real consumer discount rates, such as the actual impacts of appliance purchases on consumer savings, indebtedness or consumption, and expressed or imputed consumer preferences. While such data, if it were to become available, might provide a stronger analytical basis for DOE's choice of discount rates, it is considered unlikely that such data would have a significant effect on the range of values considered in the current analysis.

7.2.2.12 Fuel Use of Water Heater and Clothes Dryer

Definition. The fuel used to heat water in the water heater and the fuel used to provide heat in the clothes dryer.

Approach. When using the Crystal Ball™ distribution option on the spreadsheet, the distribution of fuel used is determined by the sampling of the RECS households. The fuel type used for the water heater and the clothes dryer are provided in the RECS database. Only those houses having both a clothes washer and dryer are included in the sample. Households using either electricity, natural gas, fuel oil or LPG are sampled. The DOE test procedure on which reported energy use is based accounts for the fact that not all clothes washed in a clothes washer are dried in a clothes dryer.

The DOE test procedure assumes an electric water heater and an electric dryer. The DOE test procedure is used for the Rebuttable Payback calculation.

Assumption. The distribution of fuel use as provided by RECS is shown in Table 7.5. Currently only the households in the RECS data base using these fuels are sampled using the Monte Carlo method.

Table 7.5 Shares in Households of Water Heaters and Dryers by Fuel Type

Water Heater	Dryer	Percent of Households
Electric	Electric	40.3%
Electric	Gas	0.5%
Gas	Electric	33.9%
Gas	Gas	18.5%
Oil	Electric	3.7%
Oil	Gas	0.2%
LPG	Electric	2.9%

Source: EIA, RECS 1993

7.2.2.13 Year to Start Date

Definition. This is the year at which a new standard is expected to become effective.

Approach. The LCC is calculated for all households as if they each purchase a new washer in the year the standard takes affect. The cost of appliances are based on this year, however, all dollar values are expressed in 1997 dollars. Annual energy prices are included for the life of the washer.

Current Assumption. The new energy efficiency standard for clothes washers is assumed to take effect in the year 2004.

7.2.2.14 Base Case Design

Definition. This is the cost and efficiency of the starting point to which different improvement levels of washers are compared.

Approach. AHAM supplied cost and efficiency data for a baseline and nine higher efficiency levels. The user can select any level against which to compare higher efficiency levels.

Assumption. The default assumption for the base case design is the baseline design option. The baseline MEF is defined as the efficiency level that would just meet the current minimum efficiency requirements, with some assumptions made from converting from EF (Energy Factor) to MEF (Modified Energy Factor). The energy usage values supplied for the baseline case or any other MEF level are based on a clothes washer the manufacturers would build if that level became the new minimum efficiency level. In some cases, the manufacturer would build a more efficient washer than required. See Chapter 4, Engineering for more detail.

7.2.2.15 Standard Case Design

Definition. The improved efficiency level for comparison with the base case design.

Approach. The spreadsheet user selects the level for the analysis.

Assumption. Analysis is done for all levels for which data were provided.

7.2.3 LCC Results

This section presents results for life-cycle cost (LCC) for the efficiency improvement levels specified in the Engineering Analysis. Results presented here are based on the inputs described in section 7.2.2. Since the value of most inputs are uncertain and must be represented by a distribution of values rather than a discrete value, the results are presented here as a distribution of values. Where distributions are shown, the mean value of the distribution is also presented.

LCC results are presented as differences in the LCC relative to the baseline clothes washer design. As mentioned previously, the LCC differences are depicted as a distribution of values. The primary results are presented in two types of charts: 1) a *frequency chart* showing the distribution of LCC differences with its corresponding probability of occurrence and 2) a *cumulative chart* showing the cumulative distribution of LCC differences along with the corresponding probability of occurrence. In each chart, the mean LCC difference is provided along with the percent of the population for which the LCC will decrease. Complete results are presented in Appendices F.1 and F.2.

In the explanation below, the two charts depicting the case for a 1.089 MEF level (a 25% reduction in energy use) are used (Figure 7.14 and 7.15). In either chart (frequency or cumulative), the mean change (reduction of $211 in the examples here) is shown in a text box next to a vertical line at that value on the x-axis. The phrase “Certainty is 87.35% from -Infinity to $0” means that 87% of households will have reduced LCC with the increased efficiency level compared to the baseline efficiency level. In the figure caption “Reference case” refers to the scenario of using the AEO99 reference economic growth assumption.

Figure 7.14 is an example of a *frequency chart*. The y-axes show the number of households (“Frequency” at right y-axis) and percent of all households (“Probability” at left y-axis). In this example, 10,000 households were examined (“10,000 trials”) and all results are displayed (“0 outliers”). The x-axis is the difference in LCC between a baseline efficiency level and a higher efficiency level (in this example, MEF is 1.089, a 25% energy reduction). The x-axis begins with negative values on the left, which indicate that standards for those households provide savings (reduced LCC). Reduced LCC occurs when reduced operating expenses—energy and water—more than compensate for increased purchase expense. In Figure 7.14, going from the baseline efficiency level to the 1.089 MEF level provides households with an average LCC reduction of $211, and range from reductions of $1,686 (at the left) to increases of $140 (at the right) depending upon the household. (The minimum and maximum values cannot be read with precision for the graph, but rather, the program provides them in a statistical summary.)

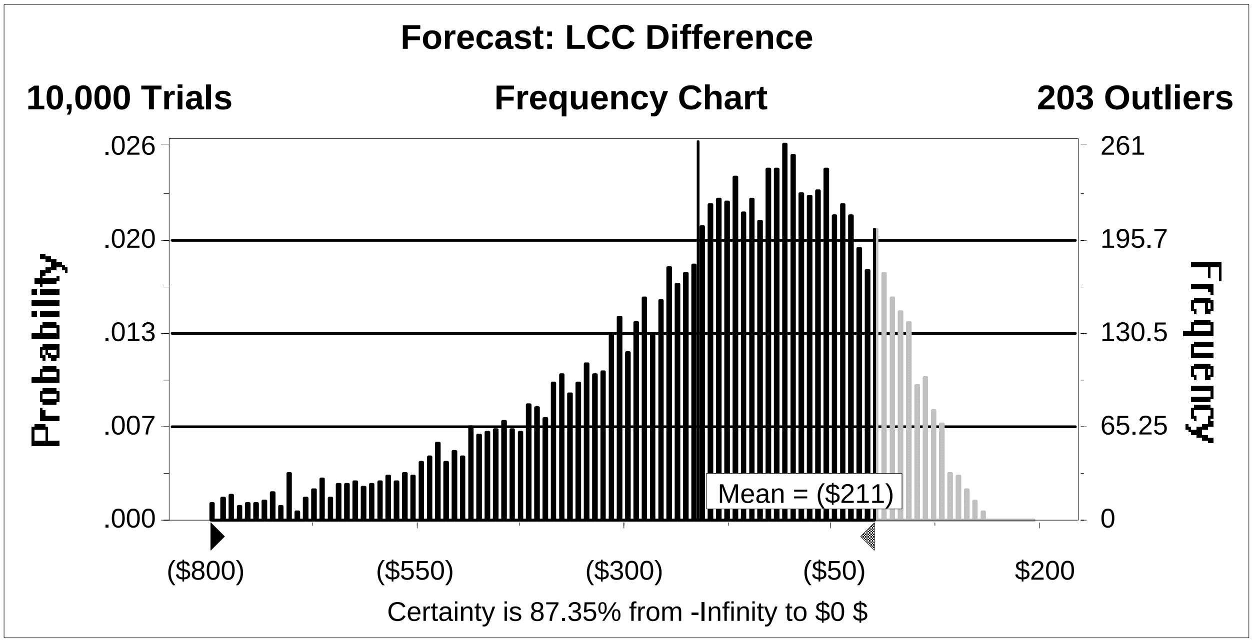

Figure 7.14 MEF = 1.089, Reference Case. Frequency Chart of LCC Differences

The vertical axis in Figure 7.15 is the cumulative probability (left axis) or frequency (right axis) that the LCC difference will be less than the value on the horizontal axis. Starting at the left, there is a 0% probability that a household will have a reduction in LCC larger than $1,686 in absolute value. Toward the middle, there is a 50% probability that a household will have a reduction in LCC larger than about $166. At the right, there is a 100% probability that a household will have either a decrease in LCC or an increase in LCC of less than $140.[a]

[a] See Table 7.6 for intermediate values.

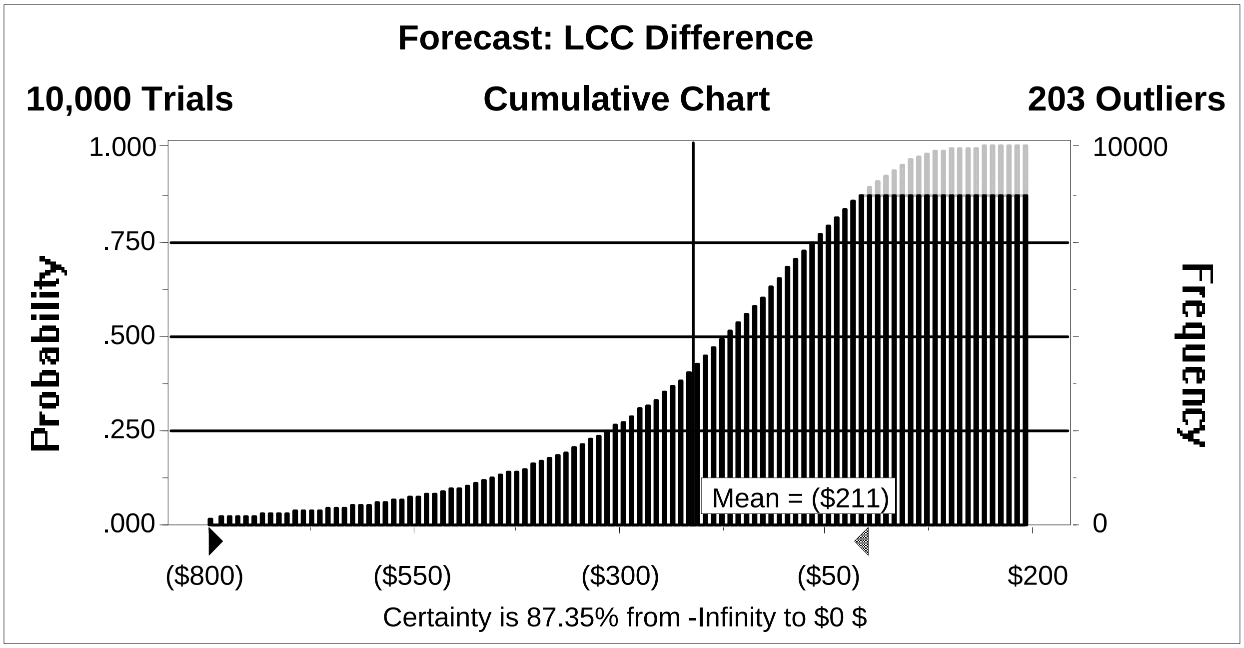

Figure 7.15 MEF = 1.089, Reference Case. Cumulative Chart of LCC Differences

Figure 7.16 shows the LCC distribution for the baseline case. This is the distribution of life-cycle costs that all standard level life-cycle costs are compared to.

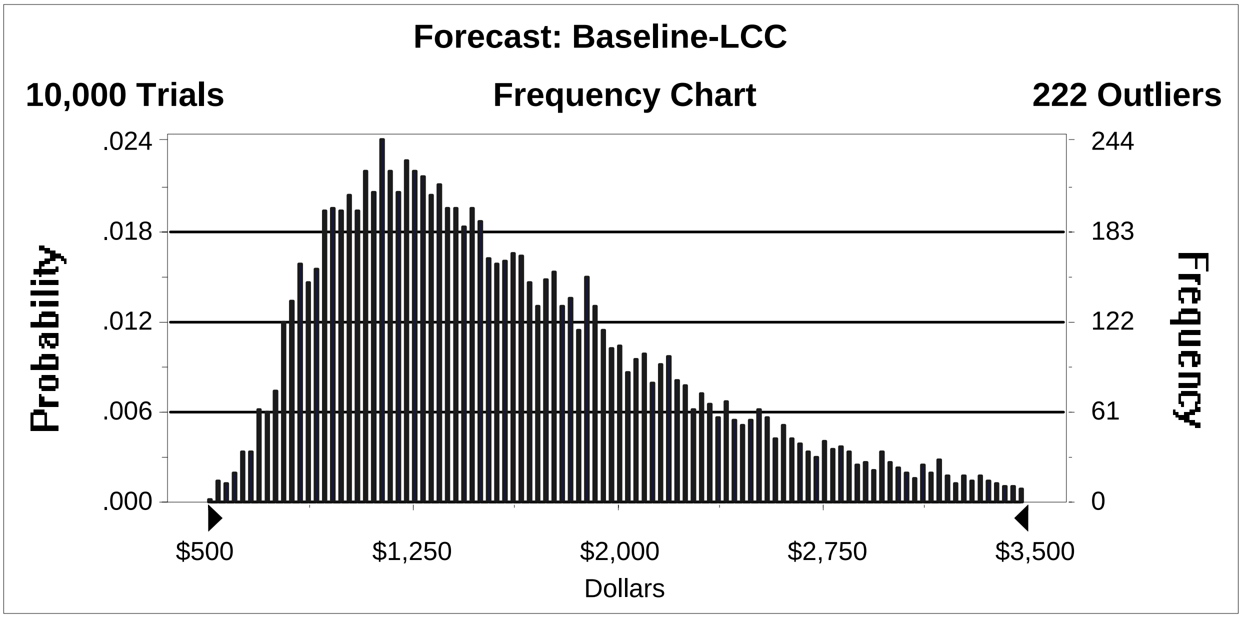

Figure 7.16 Baseline Life-Cycle Cost Distribution

Appendix G of the TSD contains the *frequency* and *cumulative charts* for all the efficiency levels and for high and low sensitivities. These charts provide more complete information than summary statistics, but a summary of the change in LCC from the baseline by percentile groupings (i.e., of the distribution of results) is given below in Table 7.6.

Table 7.6 Summary of LCC Results for the Reference Case

Trial Std. Level	MEF	Change in LCC from Baseline[1] Shown by Percentiles of the Distribution of Results[2] (values in $)								Percent with LCC Less than Baseline
		0	10	25	50	75	90	100	Mean	
	0.860	(92)	(34)	(25)	(16)	(11)	(7)	(1)	(19)	100
	0.908	(267)	(78)	(54)	(35)	(22)	(15)	19	(42)	99
	0.961	(458)	(131)	(88)	(54)	(33)	(18)	60	(66)	96
1	1.021	(619)	(149)	(93)	(52)	(22)	19	136	(61)	84
2	1.089	(1,686)	(491)	(311)	(166)	(59)	13	140	(211)	87
4	1.257	(2,341)	(663)	(406)	(194)	(33)	111	616	(242)	79
5	1.362	(2,462)	(670)	(414)	(192)	(35)	115	662	(243)	80
	1.485	(2,323)	(609)	(356)	(132)	44	205	721	(178)	69
6	1.634	(2,198)	(611)	(357)	(126)	52	203	656	(176)	69
3	1.04 MEF in 2004	(880)	(235)	(150)	(81)	(34)	0	126	(103)	90
	1.26 MEF in 2007	(2,487)	(701)	(427)	(208)	(38)	102	598	(260)	81

[1] The baseline LCC, based on shipment weighted averages of the most likely costs, is $1,633
[2] For sample size of 10,000 trials. Energy price trends are from AEO99. Operating costs include water.

Each row in Table 7.6 corresponds to the impacts on a population of households from a possible standard level. For example, for a MEF of 1.089, a 25% reduction in energy, the sample household with the largest reduction in LCC saves $1686 compared to the baseline. This result is in the "0" percentile column. For the same MEF of 1.089, the sample household with the largest increase in LCC, $140, is represented in the "100" percentile column. In between, 10% of sample households lower LCC by at least $491, 25% of sample households lower LCC by at least $311, 75% of sample households lower LCC by at least $59, and 90% of households have either reduced LCC or increases in LCC no greater than $13. The mean impact is an LCC reduced by $211 (in column "Mean"). The right-most column shows the percent of sample households for which the LCC is lower under a standards scenario.

Just prior to the publication of this analysis both RECS97 and AEO2000 data became available. We have updated the analysis for Trial Standard Level 3 using RECS97 and AEO2000 and have included it in Appendix R. As shown in Appendix R, there is no significant change in the results.

In addition to the AEO reference case scenario shown above, with expected economic growth and expected water price escalations, two sensitivity scenarios were run. Table 7.7 shows the LCC for the scenario of AEO high economic growth and high water and wastewater escalation rate. Table 7.8 shows the case for the assumption of AEO low economic growth and low water and wastewater price escalation.

Table 7.7 Summary of Life-cycle Cost Results – AEO High Growth & High Water Escalation Rate

Trial Std. Level	MEF	Change in LCC from Baseline Shown by Percentiles of the Distribution of Results (values in $)								Percent with LCC Less than Baseline
		0	10	25	50	75	90	100	Mean	
	0.860	(113)	(40)	(29)	(19)	(12)	(8)	(1)	(22)	100
	0.908	(262)	(86)	(60)	(39)	(25)	(16)	17	(46)	99
	0.961	(477)	(141)	(94)	(59)	(35)	(20)	59	(71)	96
1	1.021	(529)	(165)	(102)	(57)	(25)	16	133	(68)	85
2	1.089	(2,005)	(610)	(393)	(218)	(89)	(6)	144	(271)	91
4	1.257	(3,070)	(846)	(529)	(255)	(67)	75	645	(332)	83
5	1.362	(3,690)	(847)	(529)	(264)	(72)	79	628	(335)	83
	1.485	(2,993)	(772)	(461)	(192)	2	175	667	(258)	75
6	1.634	(3,010)	(784)	(465)	(189)	2	162	653	(265)	75
3	1.04 MEF in 2004	(791)	(273)	(179)	(100)	(45)	(7)	117	(124)	92
	1.26 MEF in 2007	(3,428)	(961)	(601)	(296)	(86)	58	631	(385)	85

Table 7.8 Summary of Life-Cycle Cost Results – AEO Low Growth & Low Water Escalation Rate

Trial Std. Level	MEF	Change in LCC from Baseline Shown by Percentiles of the Distribution of Results (values in $)								Percent with LCC Less than Baseline
		0	10	25	50	75	90	100	Mean	
	0.860	(75)	(29)	(21)	(14)	(10)	(7)	(1)	(16)	100
	0.908	(249)	(71)	(49)	(32)	(21)	(13)	19	(38)	99
	0.961	(421)	(121)	(81)	(51)	(30)	(16)	61	(61)	96
1	1.021	(483)	(135)	(86)	(48)	(18)	22	135	(54)	83
2	1.089	(1,316)	(388)	(245)	(126)	(34)	32	168	(158)	83
4	1.257	(2,022)	(522)	(312)	(138)	(2)	141	644	(169)	75
5	1.362	(2,156)	(518)	(317)	(130)	8	156	636	(163)	73
	1.485	(1,686)	(482)	(266)	(77)	89	244	643	(106)	62
6	1.634	(1,894)	(487)	(273)	(71)	85	241	679	(107)	61
3	1.04 MEF in 2004	(764)	(203)	(126)	(67)	(24)	11	126	(84)	87
	1.26 MEF in 2007	(2,012)	(515)	(307)	(133)	2	138	632	(165)	74

Figure 7.17 below summarizes the life-cycle cost results for the reference case and both high and low economic growth sensitivities.

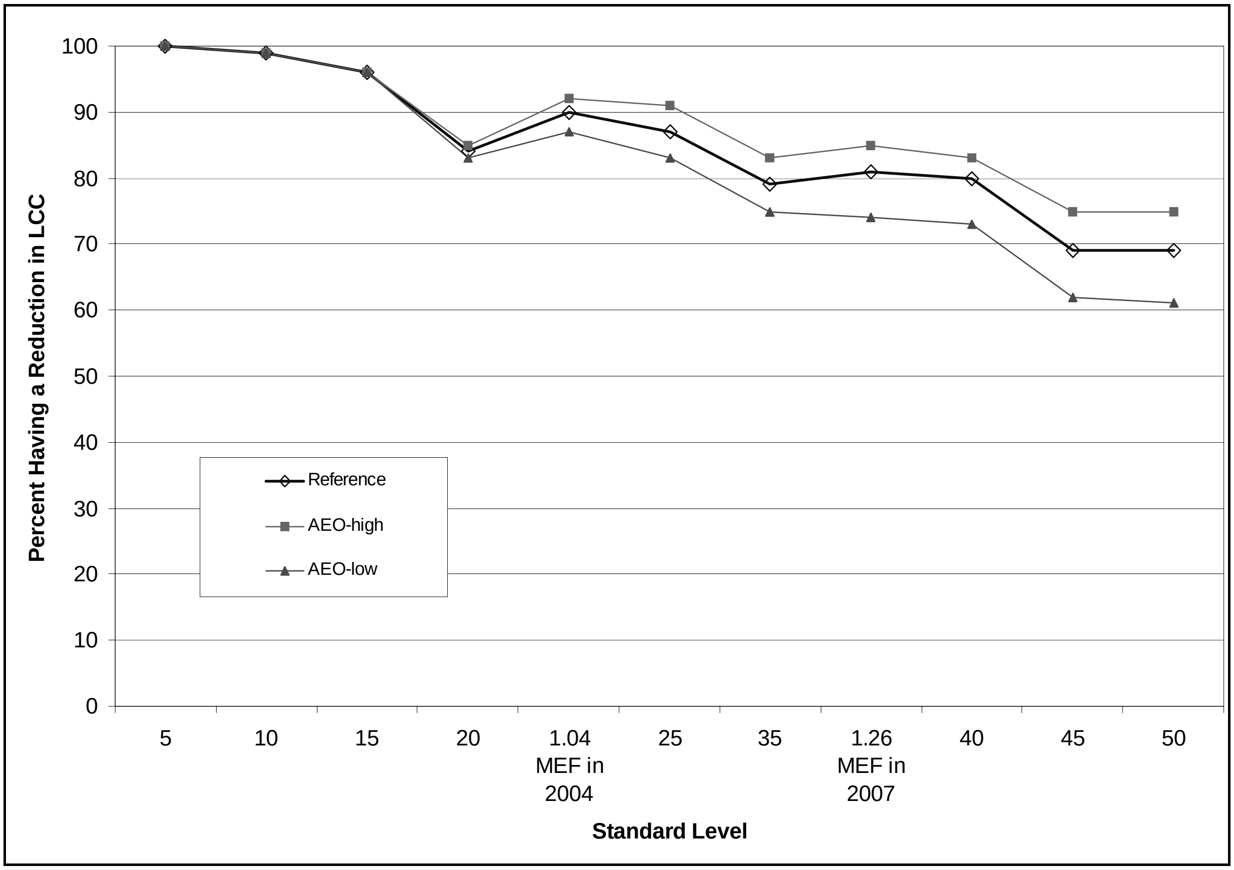

Figure 7.17 Consumers Having LCC Savings for Reference, High and Low Growth Scenarios

7.3 DISTRIBUTION PAYBACK PERIOD

7.3.1 Metric

The payback period (PBP) measures the amount of time it takes the consumer to recover the assumed higher purchase expense of more energy-efficient equipment through lower operating costs. Numerically, the PBP is the ratio of the increase in purchase expense (i.e., from a less efficient design to a more efficient design) to the decrease in annual operating expenditures. This type of calculation is known as a "simple" payback period, because is does not take into account changes in operating expense over time or the time value of money, that is, the calculation is done at an effective discount rate of 0%.

PBP is found by solving the equation

$$PAY = \frac{\Delta P}{\Delta O_1} \qquad \textbf{(4)}$$

for *PAY*, where ΔP = difference in purchase expense between the more efficient and the less efficient design options, and ΔO_1 = difference in annual operating expenses. PBPs are expressed in years. PBPs greater than the life of the product mean that the increased purchase expense is not recovered in reduced operating expenses.

7.3.2 Inputs

The data inputs to PBP are the purchase expense for each design option and the annual (first year) operating expenditures for each design option. The inputs to the operating costs are the annual energy savings, the energy price, the change in annual water consumption, and the water price. The Distribution PBP uses the same inputs as the LCC analysis described in section 7.2 except for a few exceptions described below.

Since this is a "simple" payback the fuel rates used are only for the year the standard takes effect, assumed here to be the year 2004. The price of electricity, gas and oil are those projected for that year. Similarly for water rates, a single value for the price of water and wastewater disposal is used. Discount rates are not used for the payback calculation.

7.3.3 Results

Figure 7.18 is an example of a chart showing the distribution of payback periods for a MEF of 1.089, a 25% reduction in energy consumption level. Note that the mean value of the payback period distribution (5.0 years) is provided.

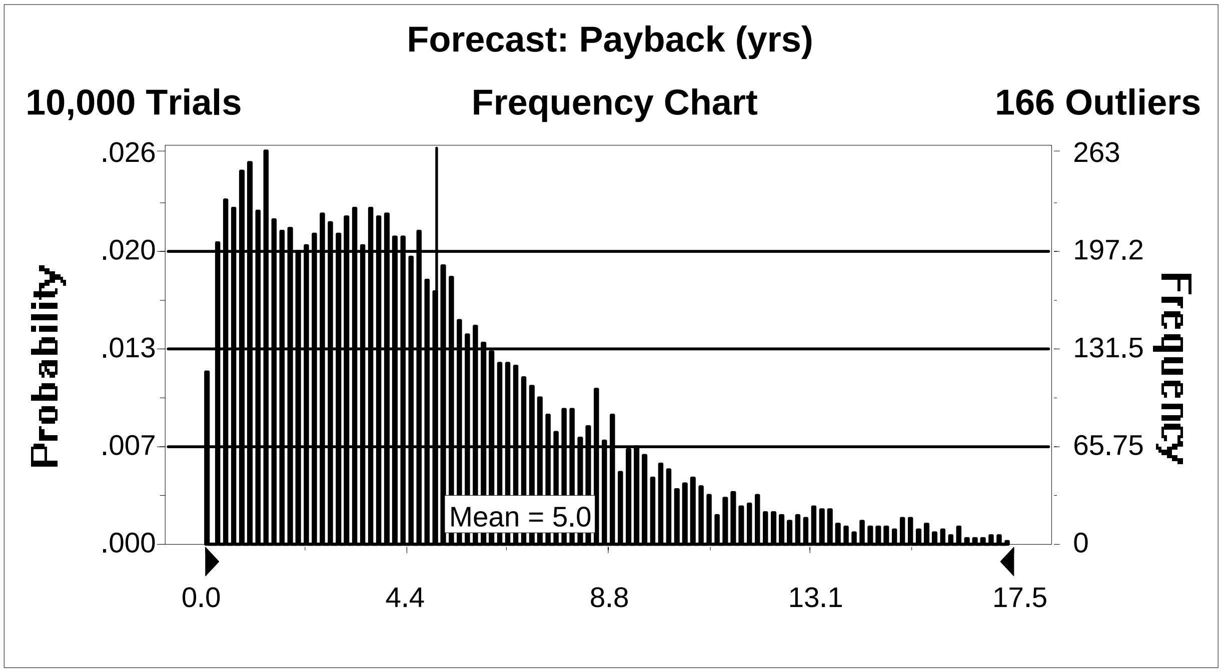

Figure 7.18 MEF = 1.089, Reference Case—Frequency Chart of Payback Periods

Appendix H contains Distribution PBP charts for all the efficiency levels. Again, these charts provide more complete information than summary statistics, but a summary of payback values by percentile groupings (i.e., of the distribution of results) is given below in Table 7.9. Each chart is the result of 10,000 Monte Carlo runs or, in other words, 10,000 samples from each of the distribution inputs. Tables 7.10 and 7.11 summarize payback period values for AEO99 high and low growth scenarios, respectively.

Table 7.9 Summary of Payback Period Results—AEO Reference

Trial Standard Level	MEF	Payback Period in Years Shown by Percentiles of the Distribution of Results[1]							
		0%	10%	25%	50%	75%	90%	100%	Mean
	0.860	0.0	0.0	0.0	0.0	0.0	0.2	3.7	0.1
	0.908	0.0	0.0	0.0	0.1	0.5	1.8	28.9	0.7
	0.961	0.0	0.0	0.1	0.2	0.6	4.2	35.2	1.4
1	1.021	0.0	0.1	0.2	0.6	6.2	12.8	65.0	4.4
2	1.089	0.0	0.9	2.0	4.0	6.7	10.0	55.8	5.0
4	1.257	0.7	2.3	3.3	5.1	8.3	13.7	94.3	7.0
5	1.362	0.9	2.4	3.3	5.1	8.3	13.7	107.4	7.0
	1.485	0.9	2.8	4.2	6.8	10.9	16.6	128.9	8.6
6	1.634	1.1	3.1	4.5	7.0	11.0	16.5	83.9	8.7
3	1.04 MEF in 2004	0.1	0.9	1.9	3.5	6.0	9.3	44.5	4.6
	1.26 MEF in 2007	0.7	2.3	3.2	5.0	8.1	13.3	93.3	6.8

[1] For sample size of 10,000 trials. Energy price trends are from AEO99. Operating costs include water prices.

Each row in Table 7.9 corresponds to the impacts on a population of households from a possible standard level. For example, for a MEF of 1.26, the sample household with the shortest payback period has a payback period of 0.7 years. This result is in the “0" percentile column. For the same MEF of 1.26, the sample household with the longest payback period of 93.3 years, is represented in the “100" percentile column. In between, 10% of sample households have a payback period of under 2.3 years and 90% of households have a payback period of 13.3 years or less. The mean impact is a payback period of 6.8 years (in column “Mean”).

Just prior to the publication of this analysis both RECS97 and AEO2000 data became available. We have updated the analysis for Trial Standard Level 3 using RECS97 and AEO2000 and have included it in Appendix R. As shown in Appendix R, there is no significant change in the results.

Table 7.10 Summary of Payback Period Results—AEO High Growth & Water Escalation Rate

Trial Standard Level	MEF	Payback Period in Years Shown by Percentiles of the Distribution of Results[1]							
		0%	10%	25%	50%	75%	90%	100%	Mean
	0.860	0.0	0.0	0.0	0.0	0.0	0.2	3.6	0.1
	0.908	0.0	0.0	0.0	0.1	0.5	1.7	21.9	0.6
	0.961	0.0	0.0	0.1	0.2	0.6	4.1	32.9	1.4
1	1.021	0.0	0.1	0.2	0.6	5.9	12.5	67.3	4.2
2	1.089	0.0	0.8	1.9	3.7	6.2	9.4	55.0	4.7
4	1.257	0.7	2.2	3.0	4.8	7.8	13.1	82.4	6.6
5	1.362	0.8	2.2	3.0	4.8	7.9	13.1	88.9	6.6
	1.485	0.8	2.6	4.0	6.4	10.3	15.7	117.4	8.2
6	1.634	1.0	2.9	4.2	6.5	10.1	15.0	111.2	8.1
3	1.04 MEF in 2004	0.0	0.9	1.8	3.3	5.6	8.7	55.9	4.3
	1.26 MEF in 2007	0.7	2.0	2.8	4.5	7.4	12.4	81.1	6.2

Table 7.11 Summary of Payback Period Results –AEO Low Growth & Water Escalation Rate

Trial Standard Level	MEF	Payback Period in Years Shown by Percentiles of the Distribution of Results							
		0%	10%	25%	50%	75%	90%	100%	Mean
	0.860	0.0	0.0	0.0	0.0	0.0	0.2	3.8	0.1
	0.908	0.0	0.0	0.0	0.1	0.6	1.9	29.2	0.7
	0.961	0.0	0.0	0.1	0.2	0.6	4.4	36.0	1.4
1	1.021	0.0	0.1	0.2	0.7	6.3	13.0	80.2	4.4
2	1.089	0.0	0.9	2.2	4.3	7.3	11.0	66.7	5.4
4	1.257	0.9	2.6	3.5	5.5	8.8	14.4	106.9	7.4
5	1.362	0.8	2.6	3.6	5.6	9.1	15.0	95.6	7.6
	1.485	0.9	3.0	4.5	7.3	11.6	17.6	108.3	9.2
6	1.634	1.2	3.3	4.8	7.5	11.7	17.2	96.8	9.2
3	1.04 MEF in 2004	0.1	1.0	2.0	3.7	6.3	10.1	65.0	4.9
	1.26 MEF in 2007	0.9	2.6	3.6	5.5	8.9	14.4	106.8	7.5

Figure 7-19 below summarizes the payback periods for the reference case and high and low economic growth sensitivities.

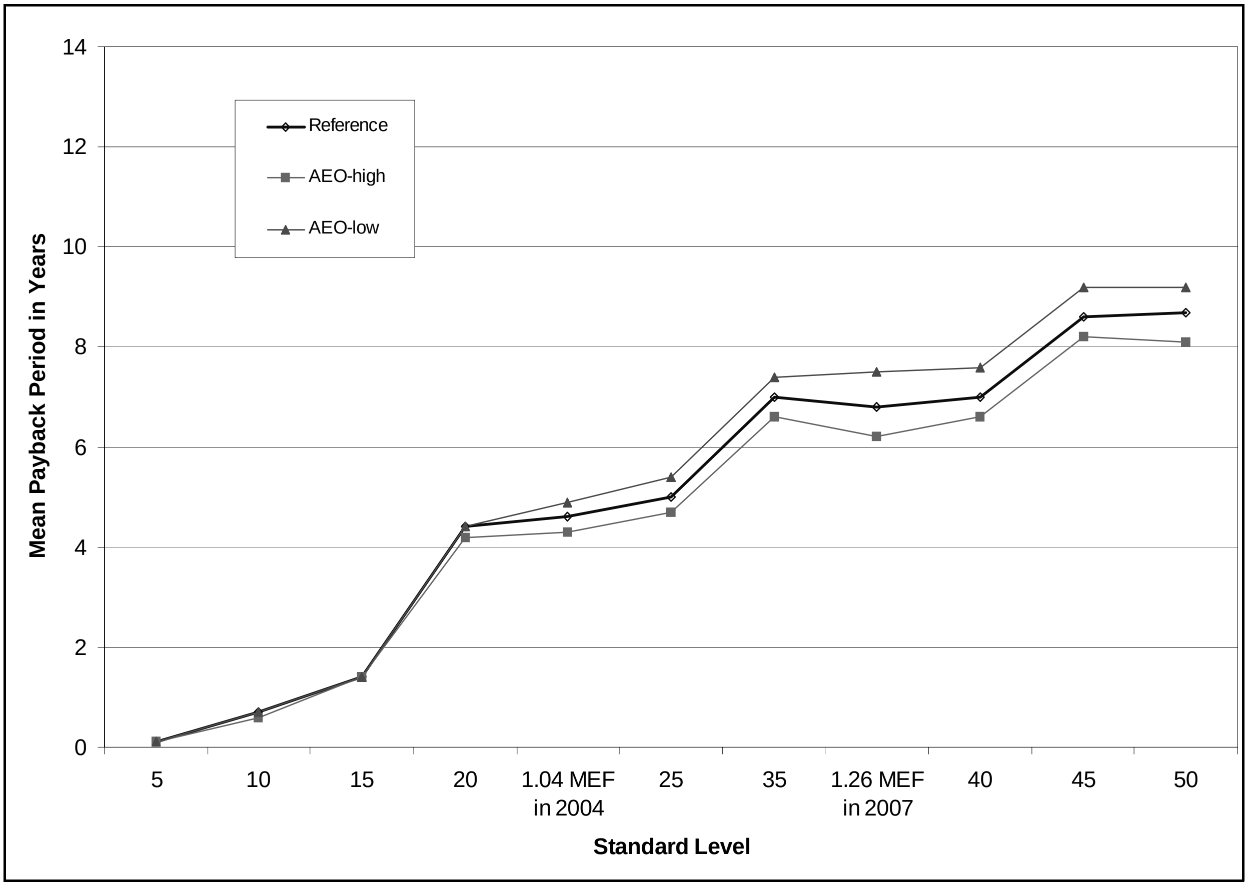

Figure 7.19 Payback Periods for Reference, High and Low Growth Scenarios

7.4 REBUTTABLE PBP

Rebuttable PBPs are presented in order to provide the legally established rebuttable presumption that an energy efficiency standard is economically justified if the additional product costs attributed to the standard are less than three times the value of the first year energy cost savings (42 U.S.C. §6295 (o)(2)(B)(iii)).

7.4.1 Metric

The basic equation for Rebuttable PBP is the same as that shown in section 7.3. Unlike the analyses in sections 7.2 and section 7.3, the Rebuttable PBP is not based on distributions and does not utilize the Crystal Ball™ option in the spreadsheet model. Rather than using distributions, the Rebuttable PBP is based on discrete values and is based on the DOE clothes washer test procedure assumptions (Appendix J1).[14]

7.4.2 Inputs

Rebuttable Presumption P*ayback Period.* Inputs differ from the *Distribution PBP* in that discrete values are used rather than distributions (where distributions are used in the LCC and Distribution PBP) for inputs. All dollar values are in 1997$. Inputs to the Rebuttable Presumption Payback are outlined below.

- For purchase expense: the shipment weighted average (SWA) of most likely price (in the AHAM supplied Engineering data) is used as the input.
- The cycles/year are 392, from DOE test procedure
- Energy per cycle for each possible standard level is obtained from the AHAM supplied data. Disaggregated values were submitted for each possible standard level for the energy use of machine, hot water and dryer energy.
- Marginal electric prices used are weighted average values for the year the standard takes effect, i.e., marginal rates adjusted using AEO projections for the year 2004.
- Water use per cycle is the gallons per cycle submitted by AHAM (see Engineering data).
- Water plus wastewater rates are the weighted average of a national distribution; $2.48/1000 gallons.
- A discount rate is not required in this calculation
- The fuel use is based on the test procedure assumption of an electric water heater and an electric dryer.
- Year to start date assumed is 2004.
- No savings in detergent costs.

Payback periods are first calculated between the new standard level and each washer efficiency being sold in the year 2004. We will use a simplified distribution of efficiencies currently being sold – for these calculations we assume a washer is either at the baseline level or at an MEF level of 1.257 (35% reduction in energy use level and assumed to be H-axis in the AHAM supplied data). The payback periods are then weighted and averaged according to the percentage of each washer efficiency sold before a new standard is enacted. For the year 2004, we predict that 9% of clothes washer sales will have an energy efficiency equivalent to a 35% reduction in energy use (as compared to the current minimum efficiency requirements). The remaining 91% of sales are assumed to have a baseline energy use as provided by AHAM for the minimum current efficiency level.

Rather than distributions, single point values for the inputs are used. These values (including cycles per year, electric fuel source, etc.) correspond to those outlined in the DOE test procedure, discussed in the Code of Federal Regulations, Title 10, Volume 3, Part 430, Subpart B, Appendix J1. The result is a single payback value and not a distribution of PBPs.

The payback is calculated for the expected effective year of the standard (e.g., 2004) and is presented below in Table 7.12.

7.4.3 Results

Table 7.12 Rebuttable Presumption Payback in Years

Market Share	91%	9%	
Standard Level	**0% (MEF=0.860) to new Standard Level**	**35% (MEF= 1.257) to New Standard Level**	**Weighted Payback**
5	0.1	NA	0.1
10	0.3	NA	0.3
15	0.7	NA	0.7
20	2.1	NA	2.1
MEF = 1.04 (in 2004)	2.5	NA	2.5
25	2.9	NA	2.9
35	4.2	NA	4.2
MEF = 1.26 (in 2007)	4.1	19.8	5.5
40	4.3	19.6	5.7
45	5.7	34.6	8.3
50	5.7	23.2	7.3

Note: NA = not applicable

In Table 7.12, the column labeled "0% to Standard" gives the payback period for each level in the Market Share column when the payback of each higher efficiency level is calculated assuming the current washer owned by the consumer is at the minimum efficiency level. The column labeled "35% to Standard" shows the payback period calculated assuming the consumer already has a washer with an efficiency of 35% (MEF = 1.257) and incurs a cost and benefits from savings for a washer with an even higher efficiency.

The results in Table 7.12 above are based on an increase of high efficiency (e.g., H-axis) sales per year of 0.5%. This percentage is of the market share that has not previously been converted over to H-axis, i.e., each year 0.5% of remaining V-axis sales are converted to H-axis sales.

The negotiated scenario of a two-tier standard with MEF levels of 1.04 becoming effective in the year 2004 and a MEF level of 1.26 becoming effective in the year 2007 is also represented. The values shown for the second tier were calculated for the year 2007. All other calculations are based on the year 2004. The effective year does not have a great impact on the payback period because only the fuel, water price and assumed stock that are high efficiency washers are different when another year is chosen.

The analysis in this TSD is based on inputs from RECS93 and AEO1999. Just prior to the publication of this analysis both RECS97 and AEO2000 data became available. We have updated the analysis for Trial Standard Level 3 using RECS97 and AEO2000 and have included it in Appendix R. As shown in Appendix R, there is no significant change in the results.

7.5 USER INSTRUCTIONS FOR SPREADSHEET

It is possible to examine and reproduce the detailed results obtained in this part of the analysis using a Microsoft Excel™ spreadsheet available on the U.S. Department of Energy Office of Codes and Standards website at: www.eren.doe.gov/buildings/codes_standards/. To execute the spreadsheets fully you will need both Microsoft Excel and Crystal Ball™ software. Both applications are commercially available.

7.5.1 What does the Life-Cycle Cost (LCC) Spreadsheet Do?

The LCC spreadsheet (**currently LccCW_10f.xls**) performs calculations for life-cycle cost and payback periods. The LCC spreadsheet operates in Excel 97 or Excel 7 (Windows 95). The Excel add-on Crystal Ball (version 4.0) allows the user to perform uncertainty analysis on key input variables.

7.5.2 What are the Worksheets in the Workbook?

The workbook **LccCW_10f.xls** includes the following worksheets:

LCC (Sample Calc) contains the input selections and a summary table of energy use, operating costs, LCC and Payback.

LCC (Distributions) contains the input selections as in the LCC (Sample Calc) sheet. The energy, cost, LCC and payback data are for the current sample if Crystal Ball is running or the last sample run if not currently running.

Water Price Dist contains price and escalation data for water.

Household Data contains marginal energy prices for each sample household, washer cycles per year for each household, and fuel use distributions.

Engineering contains the manufacturer costs for each efficiency level, as well as the manufacturer and retail markups.

Energy Price contains energy prices from the various sources of energy price information; this is used for determining the energy price escalation.

drate dist contains data from which an average discount rate and a distribution of discount rates is determined.

Lifetime contains the retirement function for clothes washers and the average clothes washer lifetime in years.

Setup this is used as an interface between user inputs and the rest of the worksheets -- do not modify this sheet.

7.5.3 How Does the User Operate the Spreadsheet?

To execute the spreadsheets fully you will need both Microsoft Excel and Crystal Ball software. Both applications are commercially available. Crystal Ball is available at http://www.decisioneering.com.

1. Once you have downloaded the LCC file from the Web, open the file using Excel. At the bottom, click on the tab for sheet **LCC (Sample Calc)** or **LCC (Distributions)**.
2. Use Excel's commands at the top **View/Zoom** to change the size of the display to make it fit your monitor. Note, that the zoom level for each of the worksheets should be set to the same value. Otherwise a bug in Excel will cause a 'Not enough system resources to display completely' error.
3. The user interacts with the spreadsheet by clicking choices or entering data using the graphical interface that comes with the spreadsheet. Choices can be selected from the box labeled **List Inputs** on either of two work sheets:

   a) **LCC (Sample Calc)** or,
   b) **LCC (Distributions**).

   A change in either input sheet also changes the other. In the box titled **List Inputs** select choices from the selection boxes for (1) energy price projection, (2) start year, (3) baseline design, (4) standard case design, (5) water heater (WH) / dryer combination, (6) water escalation rate, (7) manufacturer's cost (percentile or distribution).

   On the LCC (Distributions) worksheet, discount rate can also be entered if a value other than the default distribution is wanted. After any changes, restore this value to =drate_dist if you wish to restore the default distributions.

   On the LCC (Sample Calc) worksheet, non-default values can be specified for the discount rate, clothes washer lifetime, cycles (wash loads) per year and energy prices. Click on the

Restore Defaults command button if you want to restore the default values for these parameters in this worksheet.

4. To change assumptions on **List Inputs** click on the assumption you wish to change, and click on the new assumption from the menu.

5. This spreadsheet gives the user two methods of running the spreadsheet.

   a) If the LCC (Sample Calc) sheet is chosen, then all calculations are performed for single input values, usually an average. The new results are shown on the same sheet as soon as the new values are entered.

   b) Alternately, if the LCC (distributions) sheet is used. The spreadsheet generates results that are distributions. Some of the inputs are also distributions. The results on the LCC distribution that are shown as single values only refer to the results from the last Monte Carlo sample and are therefore not meaningful. To run the distribution version of the spreadsheet the Excel add-in software called Crystal Ball must be enabled.

7.5.4 What Is the Lcc (Sample Calculation) Sheet Used For?

LCC difference and Payback are in the LCC (Sample Calc) sheet are based on single point values. This page can be used to see the effect of changing a single parameter. It is also used to determine a rebuttable presumption payback (when inputs are based on test procedure values wherever possible).

7.5.5 How Does the User Run the Crystal Ball Simulation? (LCC Distribution Sheet)

To produce sensitivity results using Crystal Ball, you need simply select ***Run*** from the **Run** menu (on the menu bar). To make basic changes in the run sequence, including altering the number of trials, select *run preferences* from the Run menu. After each simulation run, the user needs to select *Reset* (also from the **Run** menu) before *Run* can be selected again. Once Crystal Ball has completed its run sequence it will produce a series of distributions. Using the menu bars on the distribution results it is possible to obtain further statistical information. The time taken to complete a run sequence can be reduced by minimizing the Crystal Ball window in Excel.

A step by step summary of the procedure, for running a distribution analysis, is outlined below:

1) Find the Crystal Ball toolbar
2) Click on *RUN*
3) Select *Preference* and choose from the following choices:

a) *Monte Carlo*[a]
b) *Latin Hypercube*
c) Initial seed choices and whether you want it to be constant between runs
d) Select number of Monte Carlo **Trials** (we suggest 10,000 for high accuracy calculations and 500 for quick calculations).

4) To run the simulation, follow the following sequence (on the Crystal Ball toolbar)
RUN
RESET
RUN

5) Before running Crystal Ball make sure your curser is not on any cell that has content, i.e., put curser on a blank cell).

6) Now wait until the program informs you that the simulation is completed.

7.5.6 What Kind of Output Does Crystal Ball Generate?

3) After the simulation has finished Monte Carlo run, to see the distribution charts generated, click on the Windows tab bar that is labeled *Crystal Ball*.

4) Currently, the life-cycle cost savings and payback periods are defined as **forecast** cells. The *frequency* charts display the results of the simulations, or trials, performed by Crystal Ball. Click on any chart to bring it into view. The charts show the low and high endpoints of the forecasts. The **View** selection on the Crystal Ball toolbar can be used to specify whether you want cumulative or frequency plots shown.

5) To calculate the probability of LCC savings being positive, either type 0 in the box by the right arrow, or move the arrow key with the cursor to 0 on the scale. The value in the **Certainty** box shows the likelihood that the LCC difference between the baseline and standard case will be positive. To calculate the certainty of payback period being below a certain number of years, choose that value as the high endpoint.

6) To generate a printout report, select **Create Report** from the **Run** menu. The toolbar choice of **Forecast Windows** allows you to select the charts and statistics you are interested in. For further information on Crystal Ball outputs, please refer to *Understanding the Forecast Chart* in the Crystal Ball manual.

[a]Because of the nature of the program, there is some variation in results due to random sampling when Monte Carlo or Latin Hypercube sampling is used. We recommend using Latin Hypercube.

REFERENCES

1. MTSC Inc./Management Technology Division, *Energy Capital in the U.S. Economy*, November, 1980. Bethesda, MD.

2. Erikson, J. T., *personal communication.* The Procter & Gamble Company. Letter to Peter Biermayer. Non-classified information. May 4, 1995.

3. U.S. Department of Energy, *Residential Energy Consumption Survey: Household Energy Consumption and Expenditures 1993,* October, 1995, Energy Information Administration. Report No. DOE/EIA-0321(93).

4. U.S. Department of Energy-Energy Information Administration, *Monthly Energy Review*,1999. <http://www.eia.doe.gov/emeu/mer/prices.html>

5. U.S. Department of Energy-Office of Codes and Standards, *Marginal Energy Prices Report*,1999. <http://www.eren.doe.gov/buildings/codes_standards/applbrf/pdfs/marginal_energy_price.pdf>

6. U.S. Department of Energy-Energy Information Administration, *Annual Energy Outlook 1999 with Projections to 2020*, December, 1998. Washington, DC. Report No. DOE/EIA-0383(99). <http://www.eia.doe.gov/oiaf/aeo99/homepage.html>

7. Gas Research Institute, *1998 Edition of the GRI Baseline Projection*, 1998. Arlington, VA.

8. Holte, S., Memorandum on extended price methodology used by the Federal Energy Management Program, *personal communication.* U.S. Department of Energy, Energy Information Administration. 1999.

9. Association of Home Appliance Manufacturers, *Docket No. EE-RM-94-403, Comment #83*, December 2, 1997. Comments to the Department of Energy.

10. American Water Works Association, *WaterWiser, 1998 Water Use Summary*,1998. <www.waterwiser.org>

11. American Water Works Association, *1998 Water and Wastewater Rate Survey Summary - Data courtesy of Raftelis Financial Consulting PA*,1998. <http://www.waterwiser.org/frameset.cfm?b=2>

12. Raftelis Environmental Consulting Group, *1998 Water and Wastewater Rate Survey*, 1998. Charlotte, NC.

13. Whirlpool Corporation, *Docket No. CE-RM-90-201, p. 1&2, Attachment #1,* December 12, 1990. Comments to the Department of Energy.

14. *Title 10, Code of Federal Regulations, Part 430- Energy Conservation Program for Consumer Products, Section 430, Subpt. B, Appendix J1,* January 1, 1999.